Agricultural Experiment Station, 1905

PART II
EIGHTEENTH ANNUAL
REPORT.

FORMAL REPORT OF
THE BOARD OF MANAGERS
IS PART I.

COLLEGE CATALOGUE
IS PART III.

Kingston,

R.

State of Rhode Island and Providence Plantations.

EIGHTEENTH ANNUAL REPORT

OF THE

RHODE ISLAND

AGRICULTURAL EXPERIMENT STATION,

1904-1905.

PART II.

OF THE

EIGHTEENTH ANNUAL REPORT

OF THE

CORPORATION, BOARD OF MANAGERS

OF THE

Rhode Island College of Agriculture and Mechanic Arts,

MADE TO THE

GENERAL ASSEMBLY AT ITS JANUARY SESSION, 1906.

[PARTS I. AND III. OF THIS REPORT — REPORT OF PRESIDENT AND BOARD OF MANAGERS AND COLLEGE CATALOGUE — ARE PRINTED UNDER SEPARATE COVERS.]

PROVIDENCE, R. I.:
E. L. FREEMAN & SONS, PRINTERS TO THE STATE.
1906.

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OF THE

RHODE ISLAND

College of Agriculture and Mechanic Arts.

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OTHER MEMBERS OF THE STATION STAFF.

J. P. GRAY, B. Sc	Assistant, Chemistry.
MATTHEW STEEL,* M. Sc	Assistant, Chemistry.
P. H. WESSELS, B. Sc	Assistant, Chemistry.
NATHANIEL HELME	Meteorology.
BEULAH A. HOITT	Stenographer and Accountant.
————————	Stenographer and Librarian.

The publications of the Station will be mailed free on request to any one in Rhode Island interested in agriculture. The Station desires the co-operation of the farmers of the State in the work of investigation, and any facts of special interest concerning animal or vegatable growth or disease are solicited. Visitors are always welcome. Railway station, telegraph, express, and post-office—Kingston, Rhode Island. Long distance telephone, Narragansett Pier exchange.

*Appointed expert in the Bureau of Soils of the Department of Agriculture, Washington, D. C., though still located at this Station engaged in co-operative work between the Bureau and the Station.

LETTER OF TRANSMITTAL.

To His Excellency, George H. Utter, Governor, and the Honorable the General Assembly of the State of Rhode Island, at its January Session, 1906.

KINGSTON, R. I., June 30, 1905.

I have the pleasure to present herewith, in compliance with the statute of the State and the Congressional act of March 2, 1887, the Report of the Director of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1905.

Respectfully submitted,

For the Board of Managers,

CHARLES DEAN KIMBALL,

President.

AGRICULTURAL EXPERIMENT STATION

OF THE

RHODE ISLAND COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

KINGSTON, R. I., June 30, 1905.

HON. CHARLES DEAN KIMBALL,

President, Board of Managers.

SIR:—I have the honor to transmit herewith the Eighteenth Annual Report of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1905.

Respectfully yours,

H. J. WHEELER,

Director.

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REPORT OF THE DIRECTOR.

KINGSTON, R. I., Aug. 23, 1905.

To Honorable Charles Dean Kimball, President of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts.

SIR:—It gives me pleasure to report in detail concerning the work of the Experiment Station during the year ending June 30, 1905.

DIVISION OF ANIMAL HUSBANDRY.

During the the past year Dr. Cooper Curtice, in charge of the work in animal husbandry, has continued the experiments already begun in incubation, brooding, and in the feeding of young chicks. In addition to this work the experiments with turkeys have been continued for the purpose of learning, if possible, how the "blackhead" disease of the turkey (infectious *Entero-hepatitis*, Smith) is transmitted, and how it can possibly be controlled. It will be remembered that several years ago Dr. Theobald Smith, then in the employ of the Bureau of Animal Industry of the United States Department of Agriculture, working in response to the suggestion of and in co-operation with this Station, discovered the cause of the disease to be a minute animal parasite, the presence of which causes an inflammation and an enlargement of the cæca and also a peculiar and very characteristic appearance of the liver. Later Doctor Moore, of the same Bureau of the Department, discovered that the disease could probably be transmitted from one turkey to another through the fæces. At this stage the investigations were dropped until they were

resumed again by this Station in the spring of 1902. After consulting with Doctor Smith, who was considered the best expert upon the subject of the disease, Doctor Curtice concluded that probably it could not be transmitted through the egg, and hence if other sources of contamination could be avoided it might be possible to obtain healthy birds from eggs that had been laid even by animals that were themselves diseased. With this idea in mind it was thought that if the young turkeys were reared upon land where no turkeys had been kept for several years, even though the eggs were hatched by ordinary hens and the young poults were allowed to remain with them, that there would be no danger of contagion. The experiments of that year showed, however, most conclusively, that the disease was either transmitted to the young turkey through the egg or else by the ordinary fowl or other forms of animal life which were to be found upon the Station grounds. The following spring unsuccessful attempts were made to obtain turkey eggs in considerable quantity from points in both Virginia and North Carolina, where the disease was said not to prevail. Owing to the failure of these attempts it was decided to buy some old turkeys and produce the eggs upon the Station grounds. In pursuance of this plan two lots, consisting in each case of one tom and three hen turkeys, were procured from Balitmore, North Carolina, and from Virginia. In both cases it was said that the disease was unknown in the sections from which the birds came. These two lots of turkeys were put into enclosures where no fowl of any description had been kept for many months and where it was hoped that the disease would not be acquired. During the following summer an ordinary hen in the Station poultry plant died of a disease that appeared in all particulars to be identical with the blackhead disease of the turkey. This was of special interest in view of the fact that during the preceding winter one of the turkeys from North Carolina had died of the blackhead disease.

Half of the eggs from each lot of turkeys were placed under hens and in incubators, while the others were left to be hatched by the

old birds and to roam with them subsequently in the enclosures in which they were confined.

The young turkeys which had been hatched in the incubators and those from eggs that were placed at first under hens and finally in incubators, all of which had been brooded artificially where the chances of infection from ordinary fowl were reduced to a minimum, succeeded far better than the others even from the outset, notwithstanding that the food was the same in each case. So far as concerned the environment and the danger of contamination from the poultry plant, there was practically no difference between the pens where the old turkeys reared their young and those where the animals that were artificially hatched and brooded were kept. The disease appeared at an early stage in the birds that had been hatched by the old hen turkeys, and the total mortality was great; but in the case of the birds that were kept for a time in inside enclosures the time of infection was much delayed, the total losses by the disease were much lessened, and the animals appeared in general to be in better condition. In some cases as high as 80 per cent. of the entire lot was carried through to Thanksgiving time. In brief, the evidence obtained was to the effect that the infection was brought about after the birds were placed in the outside pens, but whether it came from the old turkeys, from the ordinary fowl in the adjacent poultry yard, or from other forms of animal life, it was impossible to determine in that season. It seemed possible that the sparrows which flew back and forth from the poultry yard to the turkey pens might have carried the infection, or possibly earthworms that might burrow under the netting which separated the yards. At all events it seemed to be of vital consequence to determine just how the disease is acquired and what are the hosts which convey it to the young turkeys.

In order to throw more definite light upon this point plans were made to grow some more turkeys in the poultry yards in the spring of 1905, placing some upon the ground immediately, and holding others away from the soil and the outside pens for several weeks. In addi-

tion some turkey eggs which had been placed under hens for a time were disinfected and the hatching was finished in incubators. These were brooded in houses where the chances of infection had been reduced to a minimum by disinfection, and after the birds were sufficiently old they were placed in some pens in a piece of forest land remote from any poultry plant. Already at the time of rendering this report the birds which were left upon the grounds of the Experiment Station have died in large numbers of the blackhead disease, and even though those in the forest are many of them equally as old, none have as yet been lost by the disease.

It must be realized that the solution of the problem of the sources of infection and the discovery of the various possible hosts of the disease organism will be time-consuming, and that it may take many seasons to accomplish the purpose sought. The slowness with which such an investigation must be conducted is much greater than it would be if turkey eggs and consequently an abundance of young turkeys were available at all seasons of the year.

Thanks to the hearty co-operation of the Secretary and Assistant Secretary of Agriculture, an arrangement has been effected with the Bureau of Animal Industry of the United States Department of Agriculture by which the Bureau is to assist the Station during the coming fiscal year in connection with breeding experiments with turkeys for the purpose of controlling, if possible, the blackhead disease. For this work it is hoped to obtain wild turkeys from Florida, Virginia, and elsewhere, and to cross these perhaps among themselves and upon some of the existing breeds of domestic turkeys. At the same time it is planned, if possible, to try and increase the egg-laying capacity and to produce a breed or breeds better adapted for the production of birds of the size of quail and partridges and of birds better suited to the Thanksgiving market than some of the present domestic breeds. It is hoped that when this work is once entered upon, the means will be obtained from the Department of Agriculture for a continuation of the co-operation in future years.

So far as concerns the work of the Division of Animal Husbandry

of the Station, it is desirable that some arrangement should be perfected with the College whereby a more satisfactory subdivision of the demands upon Doctor Curtice can be provided. It is hoped such an arrangement can be made in the near future.

HORTICULTURAL DIVISION.

In the horticultural work during the past year Professor Card has been ably assisted by Mr. M. A. Blake, a graduate of the Massachusetts Agricultural College. During the year each has devoted a part of his time to the work of the College.

The experiments for the purpose of securing, if possible, a more hardy bean have been continued, and also those in Indian corn selection.

The experiments in the breeding of strawberries are making very good progress, and several promising new varieties have been produced. Some of the best of these will be multiplied as rapidly as possible and distributed for trial in different sections of the State.

The attempts to obtain crosses of the raspberry which will render it possible to materially prolong the season for that fruit are still being continued, though not with as great prospect of immediate results as the experiments in the crossing of strawberries.

In consequence of little injury to the plants during the past winter, the experiments in clover selection are more promising than last year. The casual visitor is impressed at once with the great differences that exist in the character of the individual plants. Some are early, some medium, and some late; others stand erect and have abundant leaves, while others produce stems which bear few leaves. In fact one would have difficulty in finding greater individuality in the human family than that which exists in the red clover plants produced from the seed now offered in the market.

The experiments in progress with the cauliflower the present season are of striking interest. Two lots are manured and being treated alike in every particular, excepting that one of the lots is being grown under a cloth cover similar to the ones that have been employed in

Connecticut in experiments with tobacco. The results of such an experiment depend largely upon the season, but during the present summer the cloth cover is making a great difference in the rapidity of the growth and in the degree of freedom from insect injury. The final results obtained will be embodied in a bulletin, or they will be given in a later report of the Horticulturist.

Owing to more or less injury to the blackberry bushes during the past winter, the experiments in interpollination are not in a fully satisfactory condition at present.

The two new rotations of market garden crops, one manured with stable manure and the other by means of chemical manures and cover crops, promise to be of increasing interest with the advance of time, but it is as yet much too early to form an opinion concerning their relative merits.

A new line of work has just been planned in this division, namely, that of testing various mixtures of grasses for lawns, golf links, and polo grounds. Accompanying it are trials of the effect of various chemical manures upon the kinds and the growth of the various grasses. It is hoped that these experiments will ultimately prove of material interest and value to the people of the State.

As opportunity offers the study of methods for the control of the apple-maggot is being continued.

It is hoped that this division will undertake some experimental work with the peach, for the purpose of producing, if possible, a variety that will withstand the extremes of climate which are characteristic of this State. There are said to be many isolated seedlings in the State which bear yearly and which are of fairly good quality. These might well serve as the basis for the steps at improvement, and it is hoped that persons having knowledge of such trees will call the attention of Professor Card to them without delay.

Now that the State has made provision for the construction of a new greenhouse, it is hoped that the federal appropriations for the Station may be increased sufficiently to allow of experimental work under glass, so that something can be done for this industry which

the Station has had to practically neglect owing to the lack of means and to the want of a suitable house for such work.

DIVISION OF AGRONOMY.

The Division of Agronomy is continuing the experiments with crop rotations embracing a three-year, four-year, three five-year, a six-year, and a seven-year rotation. In brief, the object of this work is to learn the best and most economical means of renovating and subsequently maintaining the fertility of the neglected and more or less exhausted soils of the State, particularly where there is little stable manure available, and where it is impracticable or too expensive to undertake such renovation by its use. In connection with this experiment three check plots are used, one of which receives the full amounts of manures used in certain of the rotations, one receives two-thirds of the full application, and another one-third of that amount. In this way it is hoped to prevent if possible the use of materially larger amounts of manures than are actually required.

In grass culture one set of plots is devoted to an experiment for the purpose of learning the most economical amount of nitrogenous manure to use per acre where the entire dependence is placed upon chemical manures and where sufficient amounts of all of the other manurial substances are present in the soil. In a similar manner a set of plots is devoted to ascertaining the most economical amounts of acid phosphate to use, and another to finding out what are the most profitable amounts of muriate of potash to employ per acre. In all of these cases the results are for guidance in the treatment of land which receives no stable manure, though incidentally they are furnishing valuable hints as to the manures that should be used in supplementing the ordinary stable manures.

A set of experiments is in progress for the purpose of learning, if possible, whether it is best to use acid phosphate, finely ground bone, basic slag meal, or Peruvian guano as a source of phosphoric acid for the top-dressing of grass-lands. Similar experiments are also in progress for the purpose of comparing the relative efficiency of the

phosphoric acid in finely ground bone meal, acid phosphate, and Peruvian guano. This is being conducted with the cruciferous plants such as beets and turnips, which are in great need of easily assimilable phosphoric acid and which may fail entirely for lack of it on land where redtop and millet will make a good growth.

In connection with alfalfa, trials are being made of the efficiency of nitro-culture, of frequent cutting during the first year, of drill culture, of broadcasting, and of seeding with oats, rye, and timothy.

There are four plots of land upon the Station farm, one of which has now become slightly alkaline (the opposite of acid), and the three others are of varying degrees of acidity. Upon these the various legumes that are of agricultural importance are being tested this season to learn the effect of the varying soil conditions upon their growth. In this connection it is of striking interest to see the difference in the influence of these conditions upon the growth of plants that are botanically closely related. For example, certain of the lupines thrive well upon very acid soil, while others are much more subject to injury by the same conditions. The beans also exhibit marked differences in this particular, for the velvet bean and the dwarf lima bean thrive better upon quite acid soil than where it has been rendered alkaline, while on the contrary Golden Wax and certain of the other string beans fail almost utterly upon the quite acid soil. Still other beans, such as the Horticultural pole bean, seem to stand midway between the two extremes as concerns the influence of these conditions.

The study of the after-effect of nine different kinds of phosphatic manures is being continued, using redtop as the plant to be grown, upon the twenty plots involved in the experiment. Already the striking ability of the redtop to secure its supply of phosphoric acid from materials which are of but slight use to plants of the beet, turnip, and cabbage family has been most plainly demonstrated. Indeed, so far as getting phosphoric acid is concerned, the redtop seems to be a scavenger among plants.

The experiment in grass culture with chemical manures is being

continued on the same land, and also the experiment in continuous Indian corn culture by the use of chemical manures, both with and without cover crops and with and without the aid of underdraining.

By way of variety-testing, trials are being made of a large number of varieties of potatoes from Europe and from various parts of the United States, with the hope of finding varieties well adapted to this State and of securing kinds that will resist the blight better than those that are being grown at present. In addition trials are being made of a large number of different varieties of both the soy bean and the southern cow-pea.

A considerable quantity of the bean *Phaseolus mungo radiatus* is being grown for distribution next season to those who may desire to make a trial of it. It yields heavy crops, is easily grown, it ripens its seed perfectly in this climate, and on account of its ability to gather nitrogen from the air it can be grown with a minimum expenditure for manure. If ground and fed to fowl or other farm animals it may be a means of materially lessening the expenditure for the highly concentrated feeding-stuffs and prove an aid in maintaining the condition of Rhode Island farms. At least it gives promise of being worthy of a trial by some of the farmers of the State, under their own conditions.

This season the Station is testing a large number of varieties of Indian corn in co-operation with the Bureau of Plant Industry of the U. S. Department of Agriculture, to see if any of the early varieties under trial are especially adapted to the needs of this State.

In addition to the experiments at the Station, arrangements were made a few years ago for the use of one-fifth of an acre of land at West Kingston, where it had been difficult to maintain a stand of good grass for more than one or two years. This land was plowed, limed, manured, and reseeded to grass, and is being top-dressed annually to see if by this procedure the land can be made to yield a profit. These results will be published later, after the experiment has been continued sufficiently long so that satisfactory conclusions can be drawn concerning it.

POT AND WATER-CULTURE EXPERIMENTS.

In addition to a limited number of pot experiments which were being conducted at the Station, arrangements were made during the winter of 1904 and 1905 by which the Bureau of Soils of the U. S. Department of Agriculture was to assist the Station in connection with its soda investigations and at the same time make a trial of a new method of pot culture devised by the Bureau for ascertaining the deficiencies of soils. In addition to the pot experiments, water-culture experiments are also being conducted for the purpose of throwing additional light upon the reason for the unproductiveness of certain soils.

CHEMICAL INVESTIGATIONS IN THE LABORATORY.

In addition to the inspection and the analysis of commercial fertilizers and feeding-stuffs, the Station has made a careful study of some of the proposed chemical methods of ascertaining the requirements of soil for phosphoric acid, and a paper upon the results of this work may be found embodied in this report.

From time to time, as opportunity has presented itself, a further study has been made for the purpose of learning, if possible, if there are certain specific poisonous substances, not necessarily acid themselves, which are present in our acid soil. Some of the results of these and related observations are included in this report, and others will be presented in a later publication.

The chemical division of the Station has also been actively engaged, in co-operation with the Bureau of Soils of the United States Department of Agriculture, in making chemical examinations of crops grown with the aid of different amounts of potassium and sodium salts, in order to ascertain the probable effect which they may have exerted, not only upon the plants, but also upon the soils themselves. This co-operation has also included a study of the toxic substances of the soil as shown by a method of pot culture devised by the Bureau for studying soil requirements.

In addition to the inspection and investigation work of the chemical division, it has been called upon to make a considerable number of analyses for the other divisions of the Station.

CO-OPERATIVE WORK WITH BUREAUS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

A special feature of the work of the Station during the summer of 1905 is the co-operative work with the various Bureaus of the United States Department of Agriculture.

The work in connection with the Bureau of Plant Industry was undertaken at the solicitation of the Bureau, and consists in making a trial of a large number of early varieties of Indian corn. In order to do this work without interference with plans for the land which had already been made, it became necessary to hire land on a farm adjoining the Station. The Station furnishes everything needed in this work excepting the seed corn.

During the spring of 1905 the Director of the Station wrote to the Department of Agriculture in Washington to see if aid could not be extended to the Station in its experiments in connection with the "blackhead" disease of turkeys. Leading out of this, arrangements have since been perfected by which the Bureau of Animal Industry is to render aid in breeding experiments with turkeys for the purpose, if possible, of controlling the "blackhead" disease. The aid to be extended the Station during the next fiscal year is limited to the amount of $2,150.

It is hoped to secure wild turkeys from Virginia, Florida, and elsewhere, and make crosses of these with various domestic breeds of turkeys, and possibly to cross them among themselves. It is hoped that in this way a more hardy breed may be developed, and that possibly birds can be secured that will be especially adapted for producing turkeys of quail and partridge sizes. It is not at all impossible that something can be done by way of raising the egg-laying capacity of turkeys and thereby increasing their prospective money-producing capabilities.

In response to an invitation, sent at the same time to the Directors of several other experiment stations, the Director went to Washington just at the opening of the new year for the purpose of a conference with the Chief of the Bureau of Soils concerning co-operative soil investigations with this Station. According to the plan proposed the Station was to furnish certain facilities for the work but was not to have the direction of any part of it, though it was to be at liberty to offer suggestions to the Chief of the Bureau. After careful consideration of the matter the Board of Managers authorized the Director of the Station to decline the proposition. The work which it was proposed to undertake was the testing at the Station of methods of making pot tests of soils and a study of supposed toxic substances which the soils might contain.

Somewhat later a request was made to the Department of Agriculture for aid in connection with the investigations which had been in progress at the Station since 1894 concerning the agricultural value of common salt and other sodium compounds and their effect upon the soil and the crop. In response to this request the Chief of the Bureau of Soils was detailed to come to Kingston for a conference concerning the matter. As a result of this conference an arrangement was perfected by which the Bureau was to extend the desired aid for the coming year, and at the same time have the opportunity of carrying out the line of experiments outlined in the previous conference in Washington.

Library.

During the year the volume and efficiency of the library have been much increased by the addition of a considerable number of individual volumes and by the binding of the current scientific periodicals. It is hoped that during the coming year the files of the publications of the United States Department of Agriculture may be completed in so far as possible, and that these may be bound for more convenient reference.

BUILDINGS AND REPAIRS.

Under the rulings of the authorities in Washington all expenditures for roads, the improvement of grounds, for fencing, plumbing, gas piping, water piping, and for repairs to buildings must be scheduled under the heading "Buildings and Repairs," and the sum that can be expended annually for all of these purposes is extremely limited in amount. For this reason, particularly in view of the poultry experiments and the consequent demands for fencing and buildings which it entails, it became necessary to ask for an appropriation of $500 from the State for repairs to the poultry buildings and yards. This appropriation, which was made at the last session of the General Assembly, will be of material aid in putting the poultry plant of the Experiment Station in a suitable and appropriate condition.

PUBLICATIONS.

During the year ending June 30, 1905, the following publications have been issued:

The Seventeenth Annual Report. pp. 161 to 289.

Bulletin No. 102, "Commercial Fertilizers." 14 pp.

Bulletin No. 103, "Experiments in Grass Culture." 30 pp.

Bulletin No. 104, "Plant Peculiarities as shown by the Influence of Sodium Salts." 47 pp.

Bulletin No. 105, "Commercial Feeding Stuffs." 16 pp.

Bulletin No. 106, "Concerning the Agricultural Value of Sodium Salts." 46 pp.

Bulletin No. 107, "Soil Treatment in Greenhouse Culture." 13 pp.

The demand for the Station publications has continued to steadily increase, and many letters have been received during the year thanking the Station for the aid which its publications have afforded. In several instances the writers have attributed their ability to succeed upon the land which they are tilling solely to the information relating to soils and to other matters which the Station has issued.

BULLETINS AND REPORTS OF THE STATION DESIRED.

It is most urgently requested that persons who have any of the earlier bulletins and annual reports of the Station which they do not desire to preserve will have the kindness to return them to the Station and thus aid in meeting the innumerable and continuous calls from libraries. Similar calls are received daily from students and farmers in all parts of the country, but such demands the Station has not been able to meet for a long time. In cases where such bulletins and reports are forwarded to the Station the persons sending them will be reimbursed for the expense attendant thereon.

STATION STAFF.

In the course of the year which has just elapsed no changes have occurred in the personnel of the heads of divisions.

The position made vacant at the close of the preceding year by the resignation of Miss Ethel Chadwick was filled by the appointment of Miss Martha Vickery as stenographer and librarian. Before the close of the year she in turn severed her connection with the Station and the position is now being filled temporarily, pending more definite arrangements.

Shortly after the beginning of the year Mr. H. M. Soper resigned to accept a commercial position, and his place was filled the following November by the appointment of Mr. Matthew Steel, a graduate of the College of Agriculture and Mechanic Arts of New Mexico. Subsequent to his regular course of study Mr. Steel had taken the degree of M. Sc. from the same college, and he had filled for a time a position as "Scientific Aid" in the Office of Experiment Stations of the Department of Agriculture, Washington, D. C. In May, 1905, Mr. Steel was appointed "Expert" in the Bureau of Soils at Washington, though still engaged in work at this Station in co-operation with that Bureau.

During the year Mr. A. E. Stene was transferred to the Extension Department of the College and Mr. M. A. Blake, a graduate of the

Massachusetts Agricultural College, was engaged as assistant horticulturist. It is due Mr. Blake to say that he has taken up his work with unusual industry and has shown exceptional adaptability to the requirements of the position.

On April 1st, 1905, Mr. J. W. Kellogg, first assistant chemist at the Station, was appointed "Expert" in the Bureau of Soils of the United States Department of Agriculture, though he still continues his labors at the Station in connection with the co-operative work in which the Station and the Bureau of Soils are engaged.

It gives me great pleasure to acknowledge the cordial support of the heads of divisions of the Station, Professors Curtice and Card.

To my associate chemist, Dr. B. L. Hartwell; to Mr. G. E. Adams, assistant in agronomy; and to Miss Beulah A. Hoitt, stenographer and accountant, my thanks are especially due for the very efficient manner in which they have attended to the many and important details of the Station work which have been entrusted to their care, and which have many times, particularly in the case of Mr. Adams, necessitated working out of regular hours and under trying conditions.

Finally, it gives me pleasure to acknowledge the hearty support of the Board of Managers, which has been granted freely in connection with every plan that has been made to further the best interests of the agriculture of the State.

Respectfully submitted,

H. J. WHEELER,

Director.

HORTICULTURAL DIVISION.

REPORT OF THE HORTICULTURAL DIVISION.

F. W. CARD AND M. A. BLAKE.

Apple-Maggot.

But little work was carried on with the apple-maggot in the season of 1904. Not many pupæ were readily available. The results were so unexpected, however, that it seems best to record them. The plan was to try the effect of tillage by placing pupæ in one frame in which the soil was stirred to a depth of two or three inches every week or ten days during the early part of the season. Others were placed in another frame in which the soil was left undisturbed. Fifteen pupæ were put in one large frame covered with wire netting in which the soil was kept stirred, and five were placed in each of three smaller frames in which the soil was left undisturbed. These pupæ were placed in the soil May 10th, being covered in all cases with about one-half inch of loose earth. These frames were watched during the time when the flies should have appeared, but none emerged, unless they escaped observation. This is so at variance with previous experience in watching the emergence of flies that we are wholly unable to account for it. So far as we are aware nothing in the handling of the pupæ would tend to prevent their development.

Observations made upon the fruit harvested from the College orchards during the fall and winter showed that apples from the old orchard, where hogs ran the year before, were comparatively free from maggots in 1904. Entire freedom could not be expected, even if the hogs had done their work perfectly, because this orchard is only a short distance removed from other trees in the younger orchard. The results, however, were sufficiently marked to show

that pasturing the orchard with stock which will promptly destroy all windfalls is a satisfactory method of controlling this pest wherever orchards are sufficiently isolated to prevent the ready entrance of the flies from neighboring orchards where the pest abounds. Fruit from trees which overhung the fence and also from one or two trees just across a roadway from this old orchard was picked up and thrown inside where it could be eaten by the hogs, but some maggots may have escaped from this fruit before it was removed. Fruit from one tree bearing sweet apples, which stood by the fence, was somewhat injured. The Fall Pippins and winter apples were almost wholly free from injury.

Many varieties in the tilled orchard, such as Hubbardston, Grimes, Mother, and earlier kinds were badly injured. This orchard receives good tillage, and if that would prove a preventive, the fruit ought to be clear. Most of the windfalls were picked up during 1904, and hogs were again placed in the old orchard.

Several cases were observed during the winter where larvæ pupated in the cellar just at the surface of the apple. The pupæ remained in the exit hole, but standing out the greater part of their length from the surface of the apple.

Apples—Resistance to Wind.

On September 8, 1904, an unusually severe wind-storm swept over this region, blowing off much of the fruit then on the trees. Observations were made upon a number of varieties as to their ability to remain on the trees in such a wind. A score was made on the scale of 1 to 10, 10 meaning that little or no fruit had fallen from the tree. This score, as recorded, is as follows:

R. I. Greening	8	Pomme Gris	7
Wagener	8	Swaar	9
Seek-no-further	7	Walbridge	9
Smith Cider	8.5	York Imperial	6
Winesap	10	Roxbury Russet	10
Mann	7.5	Canada Red	10

Tuft Baldwin	6	Rambo	8
Northwestern Greening	7.5	Genet	10
Palmer	7.5	Northern Spy	8
Yellow Bellflower	8	Missouri Pippin	9
Domine	8.5	Hubbardston	8
Ben Davis	10	Cooper Market	9
Grimes Golden	9.5	Lady	9
Mother	9	Pewaukee	7

BUSH-FRUITS.

After six years of work with bush-fruits on our Experiment Station land, the conclusion is forced upon us that the climatic conditions prevailing in that situation are decidedly unfavorable to the growth of bramble fruits. These conditions have caused a partial or complete failure of all our experiments. We have produced a number of seedlings grown from crosses, and a few of these have shown fairly promising results. A large number were ready to fruit this year, but were badly winter-killed. Some red raspberry seedlings, which were on College land on the hill, bore a satisfactory crop in 1904. These also promise well for 1905, but those on the plain have been badly winter-killed, as usual. This does not result from extreme temperatures. At no time during the past winter did the mercury reach 10° below zero, and in only a few cases as low as zero. In interior climates bush-fruits pass much lower temperatures practically unharmed. Perhaps it is the greater humidity caused by proximity to the ocean which causes more injury here.

The interpollination experiment with blackberries gave so little fruit in 1904 that no conclusions are warranted. The plot of Snyder produced only 5¼ boxes of fruit. The plot of Taylor produced only one box, while the mixed plot, made up of both varieties, produced 2¼ boxes. This difference was really a question of difference in hardiness between the two varieties. Only two or three plants of the Taylor variety bore any fruit whatever. The prospects for 1905 are no better, since the greater proportion of these plants were killed to the ground during the winter. The work in

selection, designed to determine whether propagating from plants which gave the largest yield would tend to develop a more productive strain, has met with the same fate as the other experiments. Most of the plants have been so weakened by winter injury that no yields of value could be obtained and no plants for future work. The experiment has, therefore, had to be abandoned. In some cases attempts have been made to prevent this winter-killing by laying down and covering the plants, but that did not prove satisfactory under our conditions, although it is a method frequently used in colder climates.

CORN SELECTION.

The seed of corn saved from corn selection experiments in 1903 was not well ripened when frosts appeared, and did not germinate strongly in the spring of 1904. It was planted June 3d, but the most available place was a portion of the experimental grounds which had been under tillage for several years and did not, therefore, offer such desirable conditions as sod ground gives. Although treated with commercial fertilizers and given an additional dressing of nitrate of soda, the growth was poor and weak and the corn was not well matured at harvesting time, giving an uneven stand again in 1905. The seed planted in 1904 was from the upper ear lot of the previous year, which was classified as carrying eight ears per stalk. Anything which showed a single kernel was called an ear, and some were, therefore, very poorly developed. A photograph of these stalks appears in the annual report of 1904. As there noted, selection from lower ears has been abandoned.

When harvested in the fall a count of the ears showed the following conditions:

Number of 1-ear stalks	222
Number of 2-ear stalks	291
Number of 3-ear stalks	101
Number of 4-ear stalks	8

The corn was so immature when harvested, owing, in part, to

the unusually early and severe freeze, that no attempt was made to husk and weigh the ears from the different classes. A high wind in the latter part of the summer broke down many of the stalks, which failed to straighten up again. These results show a decided reduction in the number of ears per stalk over those produced in 1903, and thereby serve to enforce a good lesson. This lesson is that while such things as selecting seed from the most productive parent plants may be important, they are of less moment than attention to the well-known cultural conditions, such as sound mature seed, planting in season, on good soil, at the proper point in the rotation, and giving good culture to the plants. These are things which everybody knows to be important but which we are very likely to neglect.

A MARKET-GARDEN ROTATION.

The object of this experiment is to determine whether it is possible to grow market-garden crops successfully without stable manure, by means of planning a rotation whereby cover-crops can be introduced from time to time for the purpose of maintaining humus in the soil. A four-year rotation was planned for this experiment, and begun in 1904. As outlined, the rotation is to be as follows:

1st year. Corn (Cory), followed by beans.
Beans, followed by corn (Crosby).

In both of these second crops clover is to be sown at the last cultivation, to afford a cover-crop during the winter and to add vegetable matter to be turned under the following spring. The object of dividing the plot and beginning with both corn and beans is to provide a better succession.

2d year. Tomatoes, followed by rye, the clover sown the fall before being allowed to grow in the spring until necessary to turn it under to plant the tomatoes. This late-planted crop affords an opportunity for a good growth of clover.

3d year. Potatoes (extra early), followed by cabbage.
Early cabbage, followed by carrots.

4th year. Onions.
Spinach, followed by celery, followed by spinach again, or
Transplanted lettuce, followed by celery.

RYE AS A COVER-CROP.

Two plots, each containing 1-10 acre, being 204 feet long by 21 feet 4 inches wide, were measured off at the west end of the plain for this experiment. The west plot, the northwest corner of which is at an iron stake driven in the ground at the angle where the highway crosses the plain, is to be treated with stable manure. The east plot, which is separated from the other by a path 4 feet wide, is to be treated with chemicals and cover-crops. No cover-crops are to be used on the plot which receives stable manure. The amount of fertilizer decided upon to use is as follows:

On the stable-manure plot, 1 cord, being at the rate of 10 cords per acre, is used. On the fertilizer plot chemicals are applied as follows:

	Per plot.	Rate per acre.
Nitrate of soda	40 lbs.	400 lbs.
Dried blood	30 "	300 "
Acid phosphate	100 "	1,000 "
Muriate of potash	30 "	300 "

With most crops the nitrate of soda is to be used in different applications as needed, the other chemicals being all applied at once in the spring. For tomatoes, which appear in the second year of the rotation, all the nitrate of soda is to be applied with the other fertilizers.

In 1904 the fertilizers required and the manure were put upon these plots May 4th and 5th. Both plots were also limed at the rate of one ton per acre. The plots were planted to corn and beans as outlined, May 6th, with six rows three feet apart on each plot. The corn was planted three kernels in a hill, with hills two feet apart. The beans were planted in drills three feet apart, with seeds about

three inches apart in the drill. A second application of nitrate of soda was made May 21st.

A note made July 5th states that corn on the plot treated with stable manure was much in advance of that on the one treated with chemicals, being nearly double in size and much more vigorous. Beans were also much more vigorous on this plot, the foliage being darker in color. The beans on both plots began to bloom at about the same time and with apparently an equal number of blooms. Corn appeared to be suckering more where stable-manure was used.

Crosby corn was planted between the beans on both plots July 11th. Beans were planted between the corn rows on both plots July 26th.

The harvesting of string-beans began on both plots July 14th and continued until August 19th. No apparent difference in time of maturing can be detected from a study of the amounts and dates of the different pickings. The total weight harvested from the plot receiving chemical manures was 221 pounds, 1 ounce; the total weight from the stable-manured plot was 347 pounds, 1 ounce.

The corn grown from the first planting was all harvested August 9th. One large ear and two small ears on the plot with chemicals had been injured by fowls, the weight of the remaining cobs and husks being 9 ounces. Nineteen large ears and four small ones had been injured in the plot with stable manure, the weight of remaining cobs and husks being 6 pounds, 8 ounces. Adding these partial weights to the weights of uninjured ears gathered gives a yield of 10 pounds, 6 ounces, from the plot which received chemicals and 124 pounds from the plot which received stable manure. The stalks from this first crop of corn were cut August 17th, the growth being good on both plots. Crimson clover was sown in the chemical plot August 19th. On the night of September 22d an unusually hard freeze occurred, the temperature falling to 24° Fahrenheit, with the result that both the corn and the beans were frozen. The beans were picked and weighed the following day, the yields being as follows:

From the fertilizer plot............................	33 lbs. 8 oz.
From the manure plot..............................	25 lbs. 3 oz.

These beans were planted between the rows of earlier corn on July 26th, and had made considerable growth before the corn was cut on August 17th. The corn on the manured plot was heavier than on the one receiving chemicals, therefore these beans were somewhat more shaded on that plot and grew more spindling. For this reason they were probably in poorer condition to stand the direct sunlight when the corn was removed than those on the plot manured with chemicals.

At the time of this freeze the second crop of corn had not reached cooking condition, therefore this part of the experiment proved a failure and no records were made. Ordinarily, sweet corn can be harvested for table use until much later than this.

A fair amount of clover lived through the winter on the plot which received chemicals, there being a reasonably good growth to turn under when the land was plowed for tomatoes, which was done June 7th, the plants being set June 9th.

SOIL STERILIZATION.

Growers of market-garden crops under glass meet with serious difficulty from fungous diseases which gain lodgment in the soil. This is particularly true in the growing of greenhouse lettuce. To avoid this trouble, growers have usually incurred heavy expense in replacing the soil of the beds with fresh garden soil at frequent intervals. Experiments and practical trials have been made in sterilizing the soil remaining in the beds after one season's work, in the hope of escaping the expense of putting in new soil, while at the same time destroying the diseases which cause trouble. When thoroughly done this practice seems to be uniformly effective in ridding the soil of diseases, but the growth of succeeding crops has not been so uniformly satisfactory. As one lettuce grower puts it, sterilizing seems to destroy the "life" of the soil so that plants do

not make the rapid, vigorous growth which gardeners demand that they shall make.

Two possible explanations of these unfavorable results suggest themselves. One is that as the sterilization is commonly done steam-pipes are placed underneath the soil, the steam turned on until the soil is thoroughly "cooked," as the gardeners say, when it is immediately shovelled over, to get at the pipes, which are moved to a new location. It has been thought that this handling of the soil while still hot and wet from the steam which has been forced into it might tend to injure the physical condition, causing it to become puddled, thereby producing unfavorable results.

Another possible explanation of the unfavorable results is that sterilization not only destroys the disease germs which are present in the soil, but it seems likewise to destroy beneficial soil organisms. We are only just beginning to realize the importance of these organisms in the growth of plants, but it is certain that they play a prominent part in plant development. The practical gardener may, therefore, be stating the exact scientific truth when he says that sterilizing destroys the life of the soil. One instance in the practical management of greenhouse lettuce seems to point in this direction. An establishment in the city of Providence procured a sterilizing apparatus and tried it for a time, getting such results as have been mentioned, namely; freedom from disease but unsatisfactory growth. The apparatus was then sold to another firm outside the city. This firm was particularly pleased with the results which were obtained from its use. Their method, however, was somewhat different from that followed by the first firm. They placed the pipes very near the surface and aimed to sterilize only a shallow layer of the surface soil. In this way the spores of the different lettuce diseases were destroyed in the surface soil, where alone they can come in contact with the plant in such a way as to cause injury. On the other hand the heat probably did not penetrate deeply enough to destroy the beneficial organisms of the soil underneath; and consequently

these organisms were able to continue their work in much of the soil which was permeated by the roots of the plants.

In the hope of securing some light on this problem, an experiment was begun in 1903, in which lettuce and radishes were grown in large pots. The soil used was made up of three parts of garden soil which was quite rich in decaying vegetable matter, mixed with one part of cow manure. After a thorough mixing this was sifted through a coarse sieve and steamed for one hour and forty-five minutes to sterilize it. This steaming was done in a tight box, the soil being placed in trays with wire bottoms to enable the steam to thoroughly permeate the whole mass. While still hot, enough soil was taken out and worked over to fill four pots, the remainder being allowed to cool before being handled. Four other pots were filled with unsterilized soil of the same kind. Those pots in which sterilized soil was placed were themselves sterilized. The experiment consisted of the following series, four pots being treated in each of the ways indicated:

1.—Soil unsterilized.
2.—Soil sterilized and handled while hot.
3.—Soil sterilized but not handled till cold and dry.
4.—Soil sterilized, handled cold, and later sprinkled with garden soil.
5.—Soil sterilized, handled cold, and nitrate of soda used.

On August 19th Deep Scarlet Turnip radish seed was planted in two of the pots in each series, Market Garden Private Stock lettuce being planted in the other pots. August 31st the pots in series No. 4 were sprinkled with soil from the College orchard. This was thought to be a fairly satisfactory garden soil, since the land among the trees had been previously used for garden crops for some time. On the same date nitrate of soda was applied to the pots in series No. 5. Other applications were made September 8th and September 17th. The first crop of radishes was harvested September 17th and the pots immediately replanted with the same variety.

The second crop was harvested October 27th. The number of plants and the weights obtained are shown in the following table:

		No. plants.	Weight, ounces.	Total plants.	Total weight
Unsterilized.................	1st crop	22	$10\frac{9}{16}$	..	..
	2nd crop	20	6	42	$16\frac{9}{16}$
Sterilized, handled while hot...	1st crop	17	4	..	..
	2nd crop	23	$7\frac{3}{4}$	40	$11\frac{3}{4}$
Sterilized, handled cold.......	1st crop	28	$7\frac{5}{8}$	..	..
	2nd crop	24	$7\frac{3}{4}$	52	$15\frac{3}{8}$
Sterilized, sprinkled with soil..	1st crop	17	$2\frac{1}{4}$	..	..
	2nd crop	24	$3\frac{7}{8}$	41	$6\frac{1}{8}$
Sterilized, plus nitrate of soda.	1st crop	20	$4\frac{5}{8}$	..	..
	2nd crop	18	$3\frac{3}{4}$	38	$8\frac{3}{8}$

This shows the order of yield to have been as follows:

First, unsterilized soil; second, soil sterilized but not handled until cool and dry; third, soil sterilized and handled while hot; fourth, soil sterilized, with nitrate of soda added; fifth, soil sterilized and sprinkled with garden soil.

The lettuce was thinned to four plants on September 17th. In some cases not that many plants remained at the close of the experiment. The plants were harvested November 9th. Those in the unsterilized soil had done the best. The others were slightly frozen or diseased. A number of weeds had appeared in the unsterilized soil but none in the rest.

The weights harvested were as follows:

	No. of plants.	Weight
Unsterilized soil...............................	6	19 ozs.
Sterilized soil, handled hot......................	3	$6\frac{3}{8}$ ozs.
Sterilized, handled cold and dry..................	4	$8\frac{5}{8}$ ozs.

As with the radishes, this shows the best results to have been obtained from the unsterilized soil.

These experiments were continued in the same manner in 1904.

Pressure of other work prevented their being started as early as would have been desirable. Absence of greenhouse facilities made it impossible that they should be carried on during the winter, when such work is usually done. Deacon lettuce and Crimson Giant Globe radish were sown in all the pots July 11, 1904. August 5th a few of the radishes had come to maturity. None were of salable size in the unsterilized soil. A single one had matured in the sterilized soil which was handled while hot, also in that which had been sprinkled with garden soil. Radishes in the pots to which nitrate of soda was added appeared to be very much better than in any of the others. Though the tops were not quite as large, they were apparently in advance of the others in maturity. There appeared to be a tendency toward a large growth of top where garden soil had been sprinkled on the surface. These radishes were inferior in quality. The yields obtained were as follows:

	Total Weight.	Weight of leaves.	Weight of roots.
Unsterilized soil................	508.90 grams	188.77 grams	320.13 grams.
Sterilized, handled while hot.....	453.56 "	206.25 "	247.31 "
Sterilized, handled cold and dry..	384.00 "	197.1 "	186.90 "
Sterilized, sprinkled with garden soil.........................	446.00 "	291.78 "	154.22 "
Sterilized, with nitrate of soda added......................	627.25 "	239.95 "	387.30 "

Arranged in order of greatest total weight, the different methods of treatment stand as follows: first, sterilized soil plus nitrate of soda; second, unsterilized; third, sterilized, handled hot; fourth, sterilized, sprinkled with garden soil; fifth, sterilized, handled cold and dry. The order of arrangement for greatest weight of roots is the same, with the exception of the last two, which change places, that sprinkled with garden soil having given the smallest weight of roots alone. Arranged in the order of early maturity, the series stands: first, sterilized soil plus nitrate of soda; second, sterilized soil sprinkled with garden soil and sterilized soil handled

hot, which rank together; third, sterilized soil handled cold; fourth, unsterilized.

Notes made upon the lettuce August 5th show that the plants in the unsterilized soil had made a fair growth. That in the pots sprinkled with garden soil had made the poorest growth of any. All the others were doing fairly well. The plants were thinned to four in each pot after they had started, but in some cases a smaller number remained at the end. The lettuce was cut and weighed September 4, 1904. The outside leaves of the plants in the unsterilized soil were greener than any of the others. The outside leaves of those in the sterilized soil handled hot had turned brown. Seed did not germinate well in the nitrate of soda pots, so that these had to be resown a few days later than the others, which may have influenced the result somewhat.

The total weights harvested were as follows :

Unsterilized soil	681.7	grams.
Sterilized, handled hot	434.2	"
Sterilized, handled cold	443.7	"
Sterilized, sprinkled with garden soil	319.2	"
Sterilized, plus nitrate of soda	445.6	"

Arranged in order of greatest weight, therefore, the lettuce stands as follows: first, unsterilized soil; second, sterilized plus nitrate of soda; third, sterilized, handled cold; fourth, sterilized, handled hot; fifth, sterilized, sprinkled with garden soil.

The garden soil used in sprinkling these pots was taken from the same field as that used in 1903. After the results were obtained this soil was tested and found to be somewhat acid. This fact may account for the unfavorable results which apparently followed its use. The object of sprinkling the surface with fresh garden soil was to determine whether by this means the beneficial soil organisms which aid in plant growth might be reintroduced. If so, a grower could sterilize the soil of his greenhouse beds, then add a light covering of fresh soil, thereby destroying undesirable spores and organisms and at the same time securing the aid of helpful ones. Thus

far our experiments seem, for some reason, to be very unfavorable to this line of action. The most important of these soil organisms are the ones which induce nitrification, that is, the process by which the nitrogen of stable-manure or other organic substances is changed into forms available for plants. It is only after having been worked over by bacteria that the major portion of the nitrogen of manure can be used in producing plant growth. It is therefore of great importance that these bacteria should be present in the soil. Nitrate of soda, on the other hand, furnishes nitrogen in a form immediately available. In the absence of soil organisms it is therefore reasonable that this material might be able to take their place so far as furnishing nitrogen is concerned. This explains its use in these experiments, and the results thus far seem favorable to such a practice.

TENT COVERING FOR VEGETABLES.

The experiments in growing vegetables under a tent were continued in 1904 with lettuce, celery and cauliflower.

Lettuce.

Lettuce showed the effect of being transplanted much less under the tent than outside. This is one of the marked advantages of the shade. Lettuce seems to grow faster underneath the tent than outside, up to the heading point, and is apparently more brittle and tender, but that outside makes more solid heads. Under the tent heads are loose and the plants run up to seed more quickly.

The weights at the time of harvesting were as follows:

Transplanted.

Date.	Outside the Tent.		Inside the Tent.	
	No. of heads.	Weights.	No. of heads.	Weights.
Aug. 3	38	13 lbs. 6 ozs.	48	18 lbs. 14 ozs.
" 9	55	15 " 14 "	44	14 "
" 30	36	20 " 11 "	36	20 " 12 "
	129	49 lbs. 15 ozs.	128	53 lbs. 10 ozs.

Average weight per head of those outside—6.19 ozs.
Average weight per head of those inside—6.57 ozs.

Grown from Seed.

Date.	Outside the Tent.		Inside the Tent.	
	No. of heads.	Weights.	No. of heads.	Weights.
Sept. 1	2	1 lb. 8 ozs.	..	
" 8	59	51 lbs. 14 "	62	37 lbs. 15 ozs.
	61	53 lbs. 6 ozs.	62	37 lbs. 15 ozs.

Average weight per head of those outside—14. ozs.
Average weight per head of those inside—9.8 ozs.

At harvesting time a head of lettuce from that grown inside and one from that grown outside were given to a number of different

families for testing. Nearly all considered that grown outside better in quality. The heads were better, though no great difference in quality could be detected. Apparently that grown outside was equally tender and of slightly better flavor. That grown inside appeared to wilt a little more quickly. One family thought that the head grown inside was less bitter than the other.

Cauliflower.

As with lettuce, cauliflower plants showed less injury from transplanting under the tent than outside, and made a better growth throughout the season. The growth of leaves was much stronger and the plants stood noticeably higher than those outside.

The yields obtained were as follows:

Outside the Tent.		*Inside the Tent.*	
DATE.	Weights.	DATE.	Weights.
Sept. 26..............	25 lbs.	....	47 lbs. 2 ozs.
Oct. 6...............	15 " 2 "	....	46 "
" 17...............	6 " 4 "	....	17 " 6 "
	46 lbs. 6 ozs.	....	110 lbs. 8 ozs.

This shows a difference of 64 pounds 2 ounces in favor of that grown inside.

It will be noted that the average yield was somewhat retarded inside the tent, although the first cutting was larger than that outside. The shade of the tent also proves an advantage in keeping the heads white, since they are less likely to discolor if not tied up at just the proper time. In fact very little extra shade is needed under the tents. A still further advantage accrues from the fact that the tent protects the plants from the attacks of insects.

Fig. 1.—Shading Experiment. Vegetables inside the Tent.

Fig. 2.—Shading Experiment. Vegetables outside the Tent.

Celery.

A few plants of Golden Self-Blanching and a few of Fin de Siecle celery were set in the tent June 28th and June 29th, with an equal number outside. These were harvested November 7th. The roots were cut off and the plants weighed without further trimming. They were then washed and trimmed and weighed again.

The yields were as follows:

Golden Self-Blanching.

Grown outside, untrimmed	8 lbs.	
" inside, "	10 "	14 ozs.
" outside, trimmed and washed	2 "	7 "
" inside, " " "	5 "	14 "

Fin dc Siecle.

Grown outside, untrimmed	25 lbs.	
" inside, "	23 "	6 ozs.
" outside, trimmed and washed	7 "	10 "
" inside, " " "	9 "	9 "

Additional plants were set both inside and outside on July 7th. These were also harvested November 7th, the yields being as follows:

Grown outside, untrimmed	92 lbs.	8 ozs.
" inside, "	87 "	15 "
" outside, trimmed and washed	40 "	6 "
" inside, " " "	44 "	14 "

The yield of the entire crop, including both plantings, was as follows:

Grown outside, untrimmed	125 lbs.	8 ozs.
" inside, "	122 "	3 "
" outside, trimmed and washed	50 "	7 "
" inside, " " "	60 "	5 "

It will be noted that in all cases there was a smaller percentage of waste from the celery grown under the tent than from that grown in the open. That grown inside was taller, and the leaves which were

exposed above the earth with which it was banked were somewhat greener. The stalks appeared to be a little softer. That grown outside was shorter and more stocky in growth, with more waste leaves on the outside. During growth the plants under the tent appeared more healthy. Those on the outside showed considerable rust on the leaves. This was less noticeable on those growing inside.

Plants from both lots were given to different families for testing. All except one considered that grown outside to be of better quality.

Temperatures.

To determine the effect of the tent upon temperature, observations were made at different times during July and August. These temperatures were taken from hotbed thermometers placed in the soil. Toward the end of this period the one inside was partially shaded by the larger growth of cauliflower leaves, which probably made the differences greater than they otherwise would have been. As recorded these temperatures are as follows:

Date.	Hour.	Temperature.
July 13	11 A. M.	4° cooler in tent.
13	2:30 P. M.	8° " " "
14	8 A. M.	6° " " "
14	3 P. M.	6° " " "
15	7:30 A. M.	6° " " "
15	2:30 P. M.	3° " " "
16	10 A. M.	1° " " "
18	12 M.	4° " " "
19	8 A. M.	1° " " "
19	9:30 A. M.	5° " " "
20	10 A. M.	9° " " "
20	3:30 P. M.	6° " " "
26	10:30 A. M.	4° " " "
27	8 A. M.	2° " " "
27	4 P. M.	1° " " "
Aug. 1	10:30 A. M.	3° " " "
3	7:30 A. M.	6° " " "
4	1 P. M.	1° " " "

Date.	Hour.	Temperature.
Aug. 8	1 P. M	3° cooler in tent.
11	8:15 A. M	4° " " "
12	10 A. M	4° " " "
15	7:15 A. M	10° " " "
15	3:30 P. M	10° " " "
17	7:45 A. M	4° " " "
17	3:45 P. M	6° " " "
18	1:15 P. M	9° " " "
19	7:30 A. M	12° " " "
19	9:30 A. M	12° " " "
Average		5.36° " " "

Attempts were made to determine differences in humidity, if any existed, but with the instruments available no important difference could be discovered.

STRAWBERRY SEEDLINGS.

A large number of strawberry seedlings were in fruit in 1904. In order to keep a more intelligent record of their behavior a score-card was devised and used. A copy of this score-card is presented herewith:

STRAWBERRY

Variety...

SCALE-POINTS 10-Perfect

Plant

Vigor	Disease Resistance	Frost Resistance

Fruit

Productiveness	Size	Regularity
Appearance	Texture	Quality
Fragrance	Rot Resistance	

DESCRIPTION

Plant

Leaves	
Runners	Fruiting Stems
Bloom Season	Sex

Fruit

Form Flavor
Color Color of Flesh
Calyx Core
Seeds Position Size Color
Season First Heaviest Last
General Notes
Date...................... Observer

To simplify entering the records, the following key was devised and used:

Key.

Leaves

Number: n=numerous; f=few.
Size: l=large; sm=small; m=medium.
Height: t=tall; s=short.
Color: d=dark; lt=light.
Surface: r=rugose; gl=glossy; c=curled; w=wrinkled.

Runners

st=strong; w=weak; n=numerous; l=long; s=short; f=few.

Fruiting Stems

st=strong; w=weak; l=long; s=short.

Number of Fruits

n=numerous; f=few.

Bloom

Season: e=early; m=medium; l=late.
Sex: p=perfect; i=imperfect.
Size: l=large; sm=small; m=medium.

Form

i=irregular; reg=regular; cox=coxcombed; ang=angular; fl=flattened; s=short; l=long; r=round; c=conic; o=oblate; ob=oblong; ov=ovate; obt=obtuse.

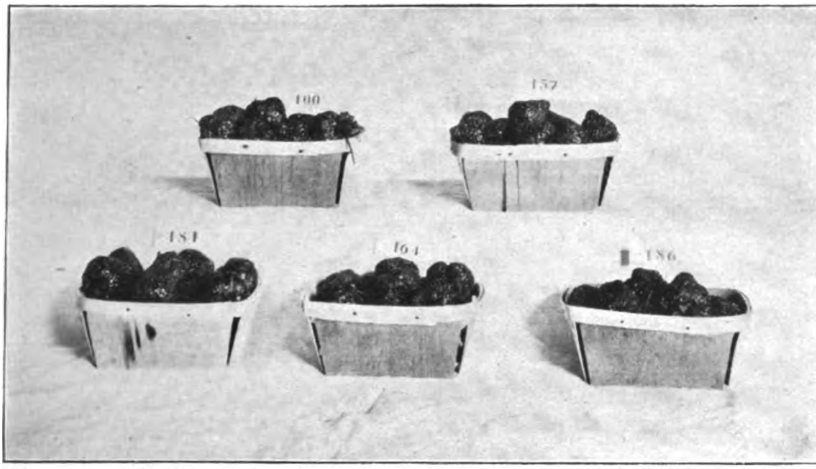

Fig. 3.—Strawberry seedlings.

No. 100. McKinley X Ridgeway.
Nos. 157 and 164. Crescent X Glen Mary.
No. 181. McKinley X Ridgeway.
No. 186. Glen Mary X McKinley.

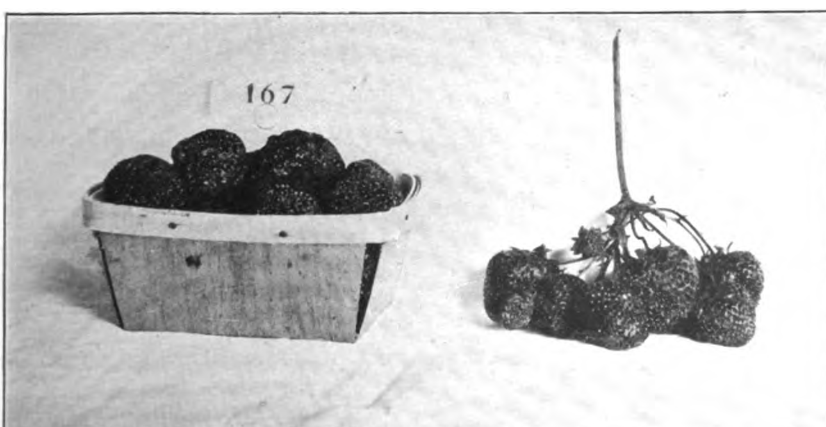

Fig. 4.—No. 167, Glen Mary X Wm. Belt.

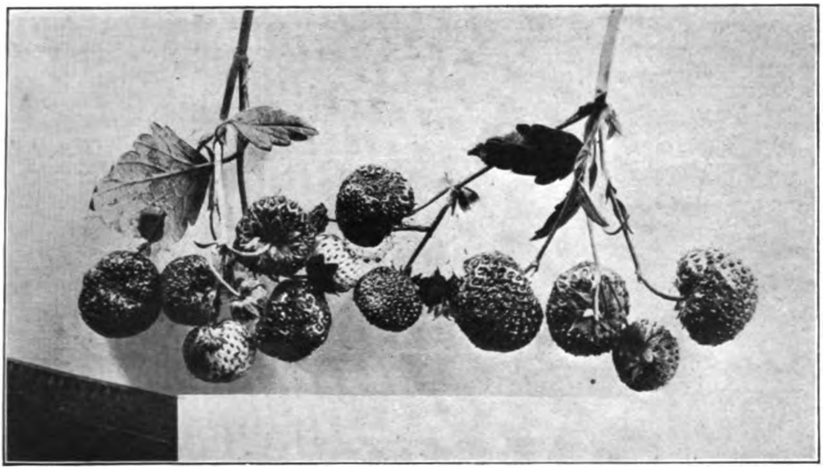

Fig. 5.—A seedling of Hunn X Ideal. Photographed July 13, 1904, showing lateness of its season.

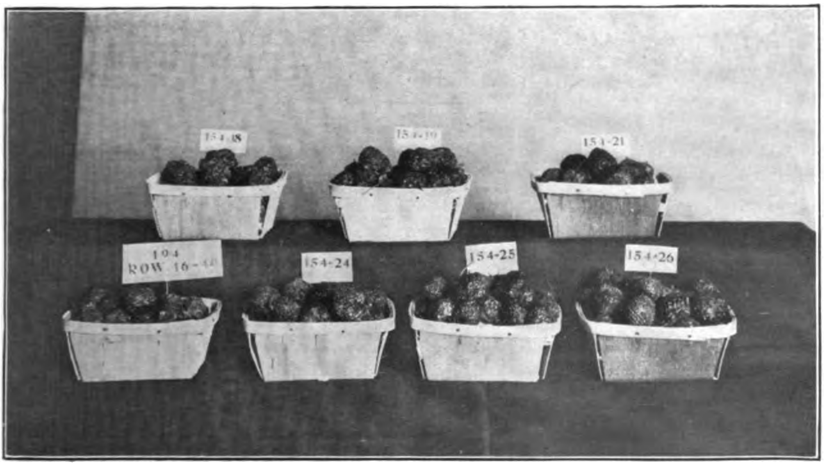

Fig. 6.—Seedlings containing one-fourth parentage of the wild strawberry.

Flavor

a=acid; sub=subacid; fl=flat; s=sweet; sp=sprightly; msk=musky.

**Color*

l=light; d=dark; o. s.=opera scarlet; n. s.=new scarlet; s=scarlet; car=cardinal; cr=crimson.

Calyx

d=depressed; c=close; r=raised; l=large; m=medium; s=small.

Core

s=solid; sp=spongy; h=hollow.

Seeds

Position

r=raised; d=depressed; d. d.=deeply depressed; p=prominent.

Color

l=light; c=colored; m=mixed.

Among the seedlings in fruit a number were selected for future observation, ten plants being taken from each. Two from which ten plants had been previously taken seemed sufficiently promising to warrant planting in larger numbers. One of these was a seedling of McKinley X Ridgeway, being known as No. 100 in our field notes. A copy of the score of this variety made in the field is here given:

STRAWBERRY

Variety, No. 100. McKinley X Ridgeway

SCALE - POINTS 10 - Perfect

Plant

Vigor 10	Disease Resistance 9	Frost Resistance

Fruit

Productiveness 8	Size 9	Regularity 8
Appearance 8	Texture 9	Quality 7.5
Fragrance 5	Rot Resistance 9	

DESCRIPTION

Plant

Leaves Large, tall, wrinkled	
Runners Good	Fruiting Stems Tall, fairly strong
Bloom Season Medium	Sex Perfect

* Based on Brainard & Armstrong's colored silks.

Fruit

Form Short, flattened | Flavor *Sub*-acid
Color Light | Color of Flesh White, tinged
Calyx Large, depressed | Core Solid, *good*
Seeds Positon Depressed | Size Medium to large | Color Light
Season First | Heaviest | Last
General Notes A fine berry, healthy and very promising.
Date................. Observer

This proved to be medium in season, the heaviest picking having been obtained July 1st. The yield was 169½ ounces from a strip of row produced by the ten plants originally set. This yield was surpassed by only one variety planted at the same time under similar conditions. The color of this berry was bright and attractive. No. 101, which was the one surpassing it in yield, was very dark and seedy in appearance. The rating for productiveness given on the score was made from appearances only, as observed in the field, not from the actual yields obtained. A basket of the fruit, in connection with that of other seedlings, is shown at Figure 3.

Another seedling which proved particularly promising in 1904 was No. 167, a seedling of Glen Mary X Wm. Belt, the score for which is also shown. This berry ranked well in yield, though surpassed by several others. In season it proved to be medium, the heaviest pickings being made June 25th and July 1st. This variety is particularly commended by its appearance. The fruit is shown at Figure 4.

STRAWBERRY

Variety, No. 167 Glen Mary X Wm. Belt.

SCALE - POINTS 10 - Perfect

Plant

Vigor 8 | Disease Resistance 9 | Frost Resistance

Fruit

Productiveness 7.5 | Size 9 | Regularity 9
Appearance 9 | Texture 7 | Quality 8.5
Fragrance 8 | Rot Resistance 6

DESCRIPTION

Plant

Leaves Large, dark		
Runners	Fruiting Stems Numerous	
Bloom Season Late	Sex Perfect	

Fruit

Form Short, conical	Flavor Sub-acid	
Color Light	Color of Flesh Like outer color	
Calyx Medium, close	Core Open, hard center.	
Seeds Position Prominent	Size Medium	Color Light
Season First	Heaviest	Last

General Notes A very fine appearing berry of good fair quality. Still some good berries July 6

Date................. Observer

One point aimed at in the production of seedlings has been to secure late ripening, coupled with other good qualities. Considerable progress has been made in this direction. Nearly all the seedlings of Hunn X Ideal ripen late. Figure 5 shows one of these, photographed July 13, 1904. This was the date of our last picking and shows the lateness of this berry, since these clusters were practically at their best on that date. A number of others surpassed any of the so-called late varieties which we have had growing on the grounds in company with them.

Among the first crosses made were several in which Wm. Belt was fertilized with pollen of the wild strawberry. The seedlings obtained from this first cross bore fruit too small to be of value, possessing in a marked degree the characteristics of the wild berry. They were inveterate plant-makers, soon filling the row completely with runners. The fruit, while small, was usually of good quality, resembling the wild berry in flavor and appearance. A few of the most promising were chosen and used for again crossing with garden varieties. A number of these seedlings were in fruit in 1904 and some of them were very promising, showing good size of fruit and desirable characteristics of plant. Some of these also retained the flavor of the wild berry to a perceptible extent. Fruit from a number of them is shown in Figure 6. These are being retained for future observation.

DIVISIONS OF AGRONOMY AND CHEMISTRY.

MISCELLANEOUS ANALYSES

(Other than those which will be published in connection with special articles).

B. L. HARTWELL, J. W. KELLOGG, AND M. STEEL.

"Hydrated" Lime.

From the Rockland Lime Co., Rockland, Me.

	Per cent.
Calcium oxid (lime)	70.90
Magnesium oxid (magnesia)	0.61

The lime was slaked by steam, and then bolted to secure it in a fine condition.

Muck (Air-dried).

From M. A. Evans, Arnolds Mills.

	Per cent.
Water	6.27
Nitrogen	1.04
Residue after ignition	39.90

Soot (From Soft Coal).

From Carl Jürgens, Newport.

I. Taken from chimney.
II. Taken from boiler tubes.

	Per cent. I.	Per cent. II.
Nitrogen	0.91	0.17

Street Sweepings.

From Carl Jürgens, Newport.

	Per cent.
Nitrogen	0.25

The amounts of phosphoric acid and potash present were too small to have any practical value.

Ashes.

From The Rhode Island Hospital, Providence.

	Per cent.
Phosphoric acid	0.92
Potassium oxid (potash)	2.18
Calcium oxid (lime)	9.00
Insoluble matter	53.27

The above ash was the residue from burning the refuse and sweepings of the hospital, including splints, bandages, animal matter, etc.

Wood Ashes.*

From The Woonsocket Spool and Bobbin Works.

	Per cent.
Phosphoric acid	2.28
Potassium oxid (potash)	11.64

The ashes resulted from the use as fuel of the refuse from spools and bobbins.

Wood Ashes.*

From F. E. Fogg, Tiverton.

	Per cent.
Phosphoric acid	2.53
Potassium oxid (potash)	14.18

Ashes.

From E. D. Smith & Co., Providence.

	Per cent.
Phosphoric acid	0.29
Potassium oxid (potash)	Trace
Calcium oxid (lime)	7.49
Ferric and aluminic oxids	73.29

These ashes were produced from coal, and from sawdust which had been used for removing the iron turnings from screws.

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* The amount of lime must have been approximately 30 per cent., but it was not actually determined. The ashes from Tiverton were from oak wood.

BLACK BONE.

From C. N. Potter, Elmwood Station, Providence.

	Per cent.
Nitrogen	0.69

This material is used in the case-hardening of steel. The phosphoric acid was not determined, but the usual content is about 29 per cent.

GUANO.

From Edmund Mortimer & Co., New York.

	Per cent. A.	B.	C.
Nitrogen	9.27	2.77	3.22
Phosphoric acid	10.58	22.42	20.53
Potassium oxid (potash)	2.29	3.57	4.07

ACID PHOSPHATE (DISSOLVED PHOSPHATE ROCK).

	Per cent. A.	B.
Phosphoric acid	16.96	15.35

This material contains from 13 to 15 per cent of "available" phosphoric acid.

FLOATS (UNDISSOLVED PHOSPHATE ROCK).

	Per cent.
Phosphoric acid	30.27

I. FINELY GROUND BONE.
II. DISSOLVED BONE.

	Per cent. I.	II.
Nitrogen	2.90	1.56
Phosphoric acid	25.03	15.37

I. STAR FISH (air-dried).
II. DRIED BLOOD.

	Per cent. I.	II.
Nitrogen	4.81	10.47

I. NITRATE OF SODA.

II. SULFATE OF AMMONIA.

	Per cent. I.	Per cent. II.
Nitrogen	15.63	21.28

MURIATE OF POTASH.

	Per cent. I.	Per cent. II.
Potassium oxid (potash)	47.43	52.60

I. HIGH GRADE MURIATE OF POTASH.

II. HIGH GRADE SULFATE OF POTASH.

	Per cent. I.	Per cent. II.
Potassium oxid (potash)	59.58	49.86

POTASSIUM CARBONATE.

	Per cent. I.	Per cent. II.
Potassium oxid (potash)	66.00	67.63

I. SODIUM CHLORID (Common Salt).

II. SODIUM CARBONATE.

	Per cent. I.	Per cent. II.
Sodium oxid (soda)	52.76	57.02

RHODE ISLAND CORN BRAN.

From Boyd Bros' Wind Grist-Mill, Portsmouth.

	Per cent.
Crude fat	3.71
Protein	7.13

COTTON-SEED MEAL.

	Per cent.
Protein	26.38

This sample contained a large amount of cotton-seed hulls. A good cotton-seed meal should contain not less than 41 per cent. of protein.

THE EFFECT OF POSTPONING THE AMMONIUM-CITRATE TREATMENT OF THE WATER-INSOLUBLE PORTION OF FERTILIZERS.[1]

B. L. HARTWELL AND J. W. KELLOGG.

It has been the custom of the Rhode Island Station to make the determinations of soluble phosphoric acid in fertilizers, and to treat the residues from the same with ammonium citrate, in all of the samples soon after they are collected. The air-dried residues from the ammonium-citrate treatment are placed in small, turned, wooden boxes, and the determinations of the phosphoric acid in these residues (insoluble phosphoric acid) are made later at any convenient time.

This course has been pursued in order to avoid the changes in the amounts of the soluble, reverted, and insoluble phosphoric acid which usually take place upon standing. Such a plan becomes necessary, when several months elapse before the fertilizer analyses are completed, in order that the amounts of the different forms of phosphoric acid found by analysis shall correspond with those actually present at the time the fertilizers were used.

The principal objection to this method of procedure is, that work involving all of the samples delays the completion of the analysis of any smaller number of the fertilizers whose publication it may be desired to hasten.

It seemed probable that if the soluble phosphoric acid were removed promptly, and the residues thoroughly air-dried, that it would not

[1] Presented before the Association of Official Agricultural Chemists of the United States, at the St. Louis meeting, in 1904.

be necessary, in order to guard against changes in the amount of insoluble phosphoric acid, to extract the reverted acid until later, whenever it was convenient. The present work was undertaken to secure some indications upon this point.

Two portions of two grams each, taken from the individual samples, were both extracted with water in the usual manner, to remove the soluble phosphoric acid, and the residues were dried in the air. Only one of the residues in each case was treated promptly, within a day or two, with the ammonium-citrate solution, to remove the reverted phosphoric acid. The residues from this treatment, as well as those from the portions which had been extracted with water only, were placed in the wooden boxes. After about fifteen weeks the residues from the extraction with water only were digested with the ammonium-citrate solution, and the insoluble phosphoric acid determined at once. At the same time the phosphoric acid was determined in the residues from the earlier treatment with ammonium citrate.

The determinations from each solution were repeated upon subsequent days, and the results (b) are placed beside the first determinations (a) from the same solutions.

The weights of magnesium pyrophosphate in grams, representing the insoluble phosphoric acid per one-half gram of fertilizer, are given below:

	Series I. Early extraction of the "reverted."		Series II. The "reverted" extracted about 15 weeks later.		Difference between I and II.
	a.	b.	a.	b.	
1........	.0080	.0084	.0080	.0073	—.0005
2........	.0187	.0185	.0179	.0180	—.0004
3........	.0113	.0114	.0121	.0122	+.0008
4........	.0142	.0142	.0149	.0148	+.0007
5........	.0178	.0177	.0195	.0177	+.0008
6........	.0244	.0245	.0223	.0223	—.0022
7........	.0181	.0182	.0184	.0177	—.0001
8........	.0075	.0077	.0081	.0078	—.0004
9........	.0125	.0124	.0124	.0119	—.0003

	Series I. Early extraction of the "reverted."		Series II. The "reverted" extracted about 15 weeks later.		Difference between I and II.
	a.	b.	a.	b.	
10........	.0122	.0125	.0135	.0134	+.0011
11........	.0163	.0163	.0167	.0160	+.0001
12........	.0135	.0142	.0147	.0146	+.0008
13........	.0237	.0236	.0233	.0228	—.0004
14........	.0156	.0156	.0162	.0164	+.0007
15........	.0160	.0160	.0138	.0134	—.0024
16........	.0137	.0139	.0143	.0138	+.0003
17........	.0264	.0258	.0209	.0207	—.0053

Before drawing any conclusions from the above differences it is necessary to know how wide a variation is liable to occur in routine work between two determinations of insoluble phosphoric acid in a given sample under our conditions, where the extractions of the soluble and the reverted phosphoric acid are made upon different days from separate portions of the sample, and where a single result only is secured from each residue containing the insoluble phosphoric acid. From an inspection of a large number of results it was found that the difference was rarely *greater* than 1.5 milligrams (0.19%), it being in most cases much less. It may be seen from the above results that in the cases of Nos. 6, 15, and 17 only was this limit exceeded; so that the differences in the remaining instances must be considered as falling within the limit of error liable to occur under the conditions of the work. Whether the reduction in amount of insoluble phosphoric acid in Nos. 6, 15, and 17 was actually caused by the postponement of the ammonium-citrate extraction, as is indicated by the results, could only be ascertained with certainty by a larger number of determinations.

If it should be proven that there is in certain isolated cases somewhat less insoluble phosphoric acid when the extraction with ammonium citrate is postponed for several months, no injustice would be done to the manufacturer, as the available phosphoric acid would become correspondingly greater.

It is interesting to note that with the other numbers taken together

there is a tendency towards an increased amount of insoluble phosphoric acid in the residue from the later extraction with ammonium citrate, although the difference in every case is within the limit of error. It is not improbable that any difference which might occur would be plus or minus, depending upon the nature of the fertilizer.

It is realized that the results herein recorded do not settle the question at hand; but they indicate that no large error will arise if, for the sake of greater convenience, the dried residues from the extraction with water are kept a number of weeks before the "reverted" phosphoric acid is removed by the ammonium citrate.

PHOSPHORIC ACID DETERMINATIONS BY THE METHOD OF IGNITION WITH MAGNESIUM NITRATE AND BY THAT OF DIGESTION WITH ACIDS.[1]

BY B. L. HARTWELL, A. W. BOSWORTH, AND J. W. KELLOGG.

The method described by A. Neumann[2] provides for the destruction of the organic matter by digesting the material in a Kjeldahl flask with a mixture of equal volumes of concentrated sulfuric and nitric acids, adding small amounts of the acid mixture from time to time, until the destruction of the organic matter is completed. Fifty grams of ammonium nitrate are then added to the cooled, diluted solution, the temperature is increased to 70° or 80°C., and the molybdic mixture added. After 15 to 20 minutes standing, the solution is filtered and the phosphoric acid determined volumetrically in the precipitate.

The method seemed to offer some advantages over the older methods, and it was decided to give it a trial in determining phosphoric acid in the oat plant and in turnips, using the method exactly as outlined except that the ammonium phosphomolybdate was dissolved in ammonium hydroxid, and the phosphoric acid determined gravimetrically in magnesium pyrophosphate, instead of using the volumetric method. A sample of oats, which yielded

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[1] This paper was published in the Journal of the American Chemical Society, March, 1905.

[2] Arch. Anat. u. Physiol., Physiol, Abt. 159 (1900); Ztschr. Physiol. Chem. 37,115 (1902–1903); Ibid 43,32 (1904). See also E. Poher, Ann. Sci. Agron. 2d. ser. 8., T. 2, 441 (1902–3).

0.0377 gram of magnesium pyrophosphate by the magnesium nitrate method of the Association of Official Agricultural Chemists, yielded by the Neumann method, with 15 to 20 minutes digestion, only 0.0309 gram. In the case of turnip roots, 0.0331 gram of magnesium pyrophosphate was obtained by the magnesium-nitrate method and 0.0326 gram by the Neumann method. Upon further digestion of the filtrate from the yellow precipitate (ammonium phosphomolybdate) secured by the Neumann method more precipitate was obtained, indicating the advisability of a longer digestion. Other determinations were next made in the same material by digesting for one hour at 65°. The oats yielded 0.0321 gram and the turnip roots 0.0319 gram as against 0.0377 and 0.0331 gram respectively by the magnesium-nitrate method. There seemed to be some difficulty in obtaining all of the phosphoric acid by precipitating with molybdic mixture according to the conditions as outlined in the method, and even upon continuing the digestion for one hour at 65°. The details of the modified method, as used in securing the results recorded on succeeding pages, and referred to herein as the acid method, are as follows: 5 grams of the substance were digested in a Kjeldahl flask. A low heat and small amount of the acid mixture were used at the beginning, the heat being gradually raised and subsequent small portions of the acid mixture added, in the manner described by Neumann, until the least amount of acid had been used which was necessary for the destruction of the organic matter, perhaps 40cc. in all. After diluting and cooling the solution was made ammoniacal, acidified with nitric acid, and treated with the molybdic mixture[1] of the A. O. A. C., to which 15 grams of ammonium nitrate per 50cc. of solution had been added. Some difficulty was experienced at first in securing a complete precipitation of the ammonium phosphomolybdate, due perhaps to the large amount of ammonium sulfate present. A large volume of solution, considerable excess of molybdic mixture, an extra amount of ammo-

[1] U. S. Dept. of Agr., Bur. of Chem., Bul. 46, p. 11, (1898).

nium nitrate, and digestion at 65° for a few hours were the conditions finally adopted.

In order to compare the results obtained by the above method with those by a well-known and thoroughly familiar method, the following was selected. To 5 grams of substance in a porcelain dish were added 10cc. of the official magnesium-nitrate solution[1] and sufficient water to allow the entire mass to be moistened. The contents of the dish were dried and ignited. The residue was treated with hydrochloric acid and, after evaporating and drying at about 120° to avoid any possibility of the results being increased by soluble silica, the mass was digested with hydrochloric acid. The filtered solution was neutralized with ammonium hydroxid, about 30 grams of ammonium nitrate, 40cc. of half strength nitrate acid and 50cc. of molybdic solution added, and the digestion conducted at 65° for an hour or more. The two methods were alike after this point, the phosphoric acid being determined in magnesium pyrophosphate as usual. The addition of the nitric acid was found necessary, under our conditions, to prevent the separation of molybdenum compounds other than ammonium phosphomolybdate, which otherwise were thrown down and interferred with clear filtration and washing. The evaporation to remove silica was perhaps an unnecessary precaution, as is indicated by the following results upon a number of different samples of oat plants. The results marked *a* were secured when evaporation and drying to render all silica insoluble were resorted to, and those marked *b* were from separate portions of the same samples when these precautions to render the silica insoluble were not taken:

GRAMS OF MAGNESIUM PYROPHOSPHATE OBTAINED FROM 5 GRAMS OF OATS.

a....0.0398	0.0453	0.0425	0.0398	0.0377	0.0333	0.0435	0.0373	0.0390
b....0.0394	0.0456	0.0430	0.0414	0.0377	0.0328	0.0434	0.0370	0.0390

The following results represent the grams of magnesium pyro-

[1] loc. cit. p. 12.

phosphate, obtained by the acid and magnesium-nitrate methods previously described, from separate five-gram portions of different samples. It may be seen that from one to three independent determinations were made in a given sample by the two methods, results upon each sample being arranged vertically:

Flat Turnip Roots.

No. of sample.	51	53	55	57	58	59
Acid method	0.0496	0.0644	0.0561	0.0630	0.0576	0.0553
	0.0516	0.0644	0.0535	0.0684	0.0620	0.0556
	0.0532	......	......	0.0656	0.0621	......
Magnesium-nitrate method	0.0493	0.0613	0.0534	0.0630	0.0560	0.0539
	0.0502	0.0613	0.0520	0.0640	0.0592	0.0555
	......	0.0611	0.0534	......	0.0584	0.0541

No. of sample.	60	61	63	65	67	69
Acid method	0.0533	0.0392	0.0340	0.0320	0.0321	0.0486
	0.0532	......	0.0344	......	......	0.0493
Magnesium-nitrate method	0.0511	0.0389	0.0323	0.0320	0.0320	0.0476
	0.0530	......	0.0339	......	......	0.0475

Oat Plant (Aerial portion).

No. of sample.	51	53	55	57	59
Acid method	0.0424	0.0477	0.0404	0.0419	0.0425
Magnesium-nitrate method	0.0398	0.0456	0.0404	0.0430	0.0414
	0.0394	0.0453	0.0376	0.0425	0.0398
	......	......	......	......	0.0390

No. of sample.	61	63	65	67	69
Acid method	0.0379	0.0354	0.0450	0.0368	0.0388
Magnesium-nitrate method	0.0377	0.0328	0.0300	0.0370	0.0390
	0.0377	0.0333	0.0435	0.0373	0.0390

The average amount of magnesium pyrophosphate obtained per five grams of material in the case of the turnip roots was 0.0493 gram by the acid method and 0.0480 gram by the magnesium-nitrate

method, which are respectively equivalent to 0.629 and 0.612 per cent. of phosphorus pentoxid. Similarly, with the oat plant, 0.0409 gram of magnesium pyrophosphate was obtained by the acid method and 0.0397 gram by the magnesium-nitrate method, which are respectively equivalent to 0.522 and 0.506 per cent. of phosphorus pentoxid.

The results by the acid method are on an average about three per cent. higher than those by the magnesium-nitrate method. It is not believed, however, that the magnesium-nitrate method failed to secure all of the phosphoric acid present in the crop, but rather that there were impurities present in the magnesium pyrophosphate obtained by the acid method; it was frequently of an abnormal color and had a reddish tint, in which case a quite strong reaction for iron was obtained. Furthermore, in a number of instances the magnesium pyrophosphate obtained by each method was dissolved in nitric acid, and upon reprecipitation and ignition the results by the two methods were more nearly alike.

By a comparison of the results with turnip roots, in which case more than one determination was frequently made by *each* of the methods, it may be seen that there was more difficulty in obtaining parallel results with the acid method than with the other.

It should be said, in explanation of the frequent wide differences in the determinations by a given method, that it was thought advisable to include *all* of the results, thereby affording an indication of the capabilities of the two methods as followed in the routine analysis of a considerable number of samples, where the time element would preclude reprecipitation for the purpose of increasing the purity of the final product.

It is recognized that a wider experience with the acid method would probably lead to desirable modifications, but for the interest of those who might wish to use the method the results are presented at this time.

NOTES ON THE USE OF ACETIC AND OF OXALIC ACID FOR EXTRACTING THE CHARRED MATERIAL IN PREPARING ASH.[1]

B. L. HARTWELL AND J. W. KELLOGG.

When material is incinerated with a view of retaining in the ash all of the potassium and sodium, it is usually advisable to extract the substance, obtained by charring at a low heat, with some solvent which shall remove the soluble ash constituents before the charred material is subjected to the higher heat necessary for complete incineration. The method[2] of the Association of Official Agricultural Chemists suggests water or acetic acid for this purpose, depending upon circumstances.

In the analysis of the ash of mixed grasses, principally timothy and redtop, it was found that about 20 per cent., after dehydrating the silica, consisted of material insoluble in hydrochloric acid. Very little "sand" could have been present, for the samples were cut from a compact turf and the only source of dirt was such dust as may have adhered to the growing plants. Practically no effervescence occurred upon adding hydrochloric acid to this ash, there being sufficient acid radicals other than carbon dioxid to combine with the bases.

It had been the general custom at this Station in the preparation of plant ash to char the substance at a low temperature and to

[1] To be read at the Annual Convention of the Association of Official Agricultural Chemists, to be held in Washington, D. C., in November, 1905.

[2] U. S. Dept. of Agr., Bur. of Chem., Bul. 46, p. 77 (1898).

extract the charred material thoroughly with hot water, in order to remove alkalies and to aid in the incineration. A single test with the hay showed that eight per cent. of the total amount of potassium and sodium was left unextracted by the hot water, even though the charred material was digested with the same for some time. It seemed, therefore, that it might be desirable in some cases to use an acid in the extraction to guard against the possibility of any volatilization of the alkalies during the final ignition; and dilute acetic acid was given a trial in comparsion with the water. It was noticed invariably that the portion of the ash from the charred, extracted material was the browner where the acetic acid was used, indicating that the proportion of iron was greater, due probably to the more thorough extraction of the calcium by the acetic acid; and also that it dissolved with greater difficulty in hydrochloric acid. In a few instances the ash from the extract and that from the charred, extracted material were kept separate, and the total silica determined in each case. The amount of silica was noticeably greater in the extract secured by water digestion than when acetic acid was used.

Chicory tops, carefully brushed to remove all soil which had spattered upon them during heavy showers, yielded an ash which generally contained, after dehydrating the silica, about six per cent. of material insoluble in hydrochloric acid. In the case of this material there was considerable carbon dioxid in the ash; but it will be noticed that the proportion of insoluble matter was much less than in the ash from hay, in spite of the fact that there was greater liability of contamination by soil in the case of the chicory tops, which were from a hoed crop. In making a comparison of water and of acetic acid for extracting the charred material of the chicory tops, a liberal quantity of the latter, after charring, was mixed and divided into two equal portions, one of which was thoroughy extracted with dilute acetic acid and the other with water. The comparsion was, therefore, more exact than in the case of the hay where the extraction was from two separately charred portions,

which may have varied slightly as regards the extent of charring. Eighty-four per cent. of the crude ash was obtained from the acetic acid extract, whereas only fifty per cent. was in the aqueous extract. Twenty-two per cent. of the total silica was found in the acetic acid extract and three per cent. in the aqueous extract. In this instance a larger proportion of the silica was extracted by the acid than by the water, while with the hay the reverse seemed to be true, due, perhaps, to the precipitation of some of the soluble silica of the highly siliceous hay, and to its retention with the charred material. The ash from the charred chicory tops, exclusive of that from the extract, was browner and dissolved with greater difficulty when acetic acid was used as the extracting solution than when water was employed, as was also true in the case of the hay. It seems likely that the more complete removal of the lime by the acetic acid is a detriment to the final incineration of the charred material from certain plant substances, resulting, as was noticed, in an ash which is more difficult to dissolve in hydrochloric acid.

The total amount of crude ash was invariably greater when acetic acid rather than water was used. This was due in part, at least, to carbon from the incomplete ignition of the acetates in the extracted material; for upon the evaporation of the extract, after combining it with the ash from the charred material, and subsequently igniting, a more or less blackened mass was obtained, which could not be burned to a light-colored ash without increasing the temperature to a degree which might result in volatilization of alkalies.

It seemed as though the difficulties in using acetic acid could be overcome by substituting oxalic acid. The latter, of course, would leave the calcium with the charred material, and, owing to the larger proportion of oxygen to carbon in this acid than in acetic acid, no carbonaceous residue would be left upon ignition. Therefore a comparasion was made between dilute oxalic acid and water for extracting the charred material from hay of similar character to that mentioned previously. Equal portions of the charred material were extracted by the two solutions, and the silica in the crude ash

from the extract and also from the charred material itself determined separately. From four different samples of hay, 90, 95, 87, and 89 per cent. respectively of the total silica was found in the charred mass which had been extracted with oxalic acid, while that left from the extraction of like material with water usually constituted less than 70 per cent. of the total silica.

It was thought that the difference in the relative amounts of the various ash ingredients in the charred substance, depending upon whether water or acid had been used in the extractions, might have an influence upon the amount of impurity which is almost invariably contained in the total silica. The insoluble matter in the ash of the charred substance from hay, referred to in the preceding paragraph, was treated, therefore, with hydrofluoric acid to volatilize the silica, and the residue soluble in hydrochloric acid was determined. The grams of residue per thirty grams of four different samples of hay are given below:

	I.	II.	III.	IV.
When the "char" was extracted with water....	.0342	.0203	.0159	.0170
When the "char" was extracted with oxalic acid	.0166	.0150	.0105	.0168

The above residues represent the following percentages of the insoluble matter from which they were obtained,

	I.	II.	III.	IV.
When the "char" was extracted with water.........	13.3	12.0	9.7	10.0
When the "char" was extracted with oxalic acid.....	6.3	6.8	4.6	7.5.

These results indicate that the insoluble matter in the ash from hay may contain less non-siliceous material if oxalic acid instead of water is used for extracting the charred substance. The insoluble matter in the ash from carrots and radishes, however, which was about one-fourth as much as from the hay, yielded no greater residue from treatment with hydrofluoric acid when water was used to extract the charred material than when oxalic acid was used.

When the samples to be analyzed are free from adhering soil, it is

advisable to treat the insoluble matter of the ash with hydrofluoric acid in order to volatilize the silica, which is then represented by the difference in weight caused by the action of the hydrofluoric acid. The residue may then be dissolved in hydrochloric acid and combined with the main portion of the solution before diluting to a definite volume. This residue is frequently of considerable magnitude, depending upon the nature of the material and the method of ignition, and often causes unsatisfactory parallels and considerable error when included in the total silica, as well as a minus error in the determinations of the non-siliceous ingredients. If any considerable amount of soil is present with the sample, it would be unwise, of course, to use hydrofluoric acid as suggested above, for the reason that the ingredients of the soil would then be included with the ash constituents and lead to plus errors.

Unless the preliminary ignition is quite thorough before the charred material is extracted, to remove the alkalies previous to complete incineration, the aqueous extract will often be dark colored from organic matter. This is not apt to be the case, however, when oxalic acid is used for extraction.

A complication will arise in the use of oxalic acid, in connection with the determination of calcium oxid, unless the oxalates are completely decomposed, for the reason that calcium oxalate will be precipitated with the iron phosphate. Some uncertainty may be felt as to whether the heat required to decompose all of the oxalates, which may be present with a large amount of ash, could lead to any volatilization of alkalies. It seems improbable, considering the combinations in which the alkalies occur at this stage, that they would be volatilized; but the only data obtained bearing upon this point are comparisons of results secured by using water for extracting the charred material from one portion of a sample, and oxalic acid for extracting the charred material from another portion of the same sample. A single determination only was made in each case, and the results per 1.25 grams of air-dry material are given below:

		Potassium and Sodium Chlorids. (gram.)		Potassium Chloplatinate. (gram.)	
		Water.	Oxalic acid.	Water.	Oxalic acid.
Carrot roots	I.	.0937	.0929	.0809	.0803
	II.	.1170	.1201	.0718	.0724
	III.	.0821	.0819	.0876	.0864
	IV.	.0744	.0723	.0938	.0925
Carrot tops	I.	.1214	.1192	.0597	.0576
	II.	.0746	.0748	.0904	.0904
Radish roots	I.	.1935	.1918	.3696	.3680
	II.	.1696	.1673	.3294	.3246

The above differences are considered within the limit of analytical error for routine work carried on in the manner described, and do not indicate any differences due to the method of extraction. It should be said in this connection that the residues from treating the insoluble matter of the ash with hydrofluoric acid were dissolved in hydrochloric acid and included with the other acid-soluble ingredients of the ash, so that any possible differences, which might have occurred from that source, would not appear in the above figures.

The amount of crude ash was generally greater when oxalic acid instead of water was used for extracting. As would be expected, there were no evidences of carbon left from the decomposition of the oxalates, and it seems probable that the amount of ash was greater because it was more thoroughly carbonated. With hay, where the evolution of carbon dioxid upon the addition of hydrochloric acid is small, the greater effervescence from the ash prepared by extraction with oxalic acid could be readily noticed.

ON THE EFFECT OF LIMING UPON CERTAIN CONSTITUENTS OF A SOIL.

B. L. HARTWELL AND J. W. KELLOGG.*

In connection with experiments conducted at this Station regarding the effect of lime upon the growth of plants, some chemical work has been done which shows certain effects of this material upon the soil itself. In 1893 the permanent plats Nos. 23, 25, 27, and 29 were set apart for determining the relative efficiency of nitrogen in nitrate of soda and in sulfate of ammonia. Since that time all of the plats have received equal annual applications of dissolved bone-black, muriate of potash, and nitrogen, and occasional additions of magnesium sulfate. Sulfate of ammonia has been used as the source of nitrogen for plats 23 and 25, and nitrate of soda for plats 27 and 29. Plats 25 and 29 have received the following applications of air-slaked lime per acre, namely: in 1893, 5,400 pounds; in 1894, 1,000 pounds; and in 1902, 1,046.1 pounds; making in all over 3.7 tons. One of the plats receiving sulfate of ammonia, No. 23, and one of those to which nitrate or soda has been added, No. 27, have never received any air-slaked lime. Miscellaneous crops have been grown across these plats, and the cultivation has been the same for all. In December of 1896 samples of the surface soil were taken from the four plats by making borings along a line extending across them. The percentages of humus† in the oven-dry soil, finer than 1-50 inch, were as follows:

* Many suggestions in connection with this work were received from Dr. H. J. Wheeler.

† The term "humus" as used in this article refers to the organic matter extracted by dilute ammonium hydroxid after a preliminary extraction with dilute hydrochloric acid. See Wiley's Agricultural Analysis, Vol. 1, p. 326 (1904), for method employed.

Sulfate of ammonia plat, unlimed	4.00
Sulfate of ammonia plat, limed	3.60
Nitrate of soda plat, unlimed	4.29
Nitrate of soda plat, limed	3.49

Samples of soil were again taken from the four plats in the spring of 1904; at this time the borings were made so that the entire plat might be represented by each sample. The percentages of humus in the oven-dry soil, finer than 1-25 inch, were as follows:

Sulfate of ammonia plat, unlimed	3.76
Sulfate of ammonia plat, limed	3.25
Nitrate of soda plat, unlimed	3.78
Nitrate of soda plat, limed	3.33

These results should not be compared with those from the year 1896, because the samples were both taken and prepared differently. Attention is directed at this time merely to the fact that the amount of humus in the limed soil is from 10 to 19 per cent. less than in the corresponding unlimed soil, when both sets of results are taken into consideration.

The following results taken from an earlier publication* of this Station show the variations in the content of humus in a soil after growing maize, oats, and rye, each for one year, in large pots which were sunk in the ground. The soil was taken from a portion of the same field in which the previously mentioned plats are located, and the limed pots received, at the beginning of the experiment, air-slaked lime at the rate of four tons per acre.

Humus in oven-dry soil.

	Per Cent.
Sulfate of ammonia pots, unlimed	3.93
Sulfate of ammonia pots, limed	3.63
Nitrate of soda pots, unlimed	3.93
Nitrate of soda pots, limed	3.42

* Annual Report, (1899) p. 155.

The following loss in weight resulted upon ignition of the soil collected in 1904 from plats 23, 25, 27, and 29, which had been oven-dried at 150°C before ignition:

	Per Cent.
Sulfate of ammonia plat, unlimed	7.12
Sulfate of ammonia plat, limed	6.88
Nitrate of soda plat, unlimed	7.24
Nitrate of soda plat, limed	6.67

The above loss by ignition can not, of course, be attributed entirely to organic matter; but it is fair, perhaps, to assume that the changes in weight due to other causes would be about equal on all of the plats, and that the smaller losses from the limed soil indicate that the total organic matter has been somewhat decreased.

In view of the smaller quantities of humus and of organic matter in the limed than in the unlimed soil, it is of interest to record the following amounts of nitrogen, calculated to oven-dry soil, in the samples collected in 1904:

	Per Cent.
Sulfate of ammonia plat, unlimed	0.223
Sulfate of ammonia plat, limed	.222
Nitrate of soda plat, unlimed	.225
Nitrate of soda plat, limed	.205

The differences in the first three results are within the limit of analytical error (about .005 per cent.); the limed plat receiving nitrate of soda being the only one which shows a decreased amount of nitrogen in the soil. It should be recalled that liberal applications of nitrogen were made annually to each plat.

The amount of humus in the limed plats is not only less, as has been recorded above, but the composition of the compounds containing humus and ash constituents is different. This is shown by extracting the soil directly with dilute ammonium hydroxid, without the preliminary treatment with hydrochloric acid as required in the determination of humus. The precipitate, formed by acidifying

this ammoniacal extract with hydrochloric acid, is dried and the further loss upon ignition is designated herein as "free" humus.*

Free Humus in Oven-dry Soil. (*Sampled in* 1904.)

	Per Cent.
Sulfate of ammonia plat, unlimed	1.47
Sulfate of ammonia plat, limed	.99
Nitrate of soda plat, unlimed	1.61
Nitrate of soda plat, limed	.96

The free humus equals 39 and 43 per cent., respectively, of the humus in the case of the unlimed plats, while with the limed ones it equals only 30 and 29 per cent., respectively, of the humus. The free humus in the samples collected in 1896 showed practically the same relation to the humus as the above.

The effect exerted by lime upon the organic matter of a given soil depends to a considerable extent upon the degree of acidity or alkalinity of the soil. It is important, therefore, to note some of the characteristics of the particular soil from which the results herein recorded have been secured. The soil contains no calcium carbonate, and turns blue litmus paper decidedly red. Many of the common agricultural plants fail to make a satisfactory growth until some alkaline material has been applied to the soil. The conditions are made worse by the addition of manurial substances which have the effect of increasing the acidity; for example, sulfate of ammonia. Nitrate of soda, on the other hand, gradually diminishes the acidity so that plants which are much injured by the conditions naturally existing in this soil manifest eventually greater benefit from liming when sulfate of ammonia instead of nitrate of soda constitutes the source of nitrogen. In fact the conditions are such upon the unlimed plat No. 23, to which sulfate of ammonia has been applied annually for a series of years as the source of nitrogen, that many varieties of plants are unable to live there.

The acidity of the soil from the four plats previously mentioned

* See method in Wiley's Agricultural Analysis, Vol. 1, p. 331.

was determined, in its natural, moist condition, in May, 1904, by the lime-water method.* The amounts of calcium oxid required per acre to neutralize the soil were found by this method to be approximately as follows:

	Pounds.
Sulfate of ammonia plat, unlimed	4,700
Sulfate of ammonia plat, limed	1,100
Nitrate of soda plat, unlimed	2,500
Nitrate of soda plat, limed	0

The idea is frequently expressed that a treatment which decreases the humus of a soil tends to diminish its productiveness. This thought, however, should be associated with the fact that the value of humus depends upon its particular character. The limed plat receiving sulfate of ammonia, for example, contains about one-seventh less humus than the unlimed one, and yet the productiveness has been wonderfully increased by the liming. There can be no doubt, however, of the advisability of maintaining a liberal supply of organic matter of the proper kind within the soil; and, where liming proves desirable, particular attention should be given to this point, because of the tendency of the lime to decrease the organic material. Unless stable manure is applied, or an occasional green crop or grass stubble is turned under, the amount of organic matter in the soil may become depleted to such an extent in the course of time as to seriously decrease the productiveness of the soil.

The exclusive use of chemical manures for long periods of years should not be resorted to without a very careful consideration of the question of the maintenance of sufficient decomposing organic matter within the soil to conserve moisture, insure a proper physical condition, liberate plant food, and so forth.

It has been shown previously that not only the amounts of humus and of free humus were less upon the limed than upon the unlimed plats, but also that the proportion of free humus was less; or, in other words, the composition of the compounds of humus and

* Veitch. Jour. Amer. Chem. Soc. 26. 661, (1904.)

inorganic matter is changed to such an extent by the liming as to materially decrease their solubility in ammonium hydroxid.

Enough determinations are recorded herewith to indicate that there is a marked difference in the composition of the ash associated with the free humus of the limed and of the unlimed plats. In the case of the unlimed plats fertilized with either sulfate of ammonia or nitrate of soda, silica composed 26 and 23 per cent., respectively, of the ash associated with the free humus, while with the corresponding limed plats the per cent. was increased to 35 and 32, respectively. On the other hand, the proportions of oxids of iron, aluminum, and phosphorus taken collectively were noticeably *less* in the ash associated with the free humus of the limed plats. It is recognized that the quantity of mineral ingredients which is precipitated together with the free humus by hydrochloric acid, and, to some extent, the composition of the same, are somewhat dependent upon the conditions of precipitation; but determinations made under similar circumstances, as these were, may be compared fairly with each other. The precentage of ash to free humus was about the same in all four soils. The color of the ash in each case indicated a large proportion of ferric oxid.

The amounts of the principal ash ingredients contained in the clear extract secured by ammonium hydroxid after the soil had been previously extracted with dilute hydrochloric acid and washed, that is, those ash constituents associated with the humus itself, were as follows:

Percentages of Certain Ingredients in the Ash Associated with the Humus. (*Samples of Soil taken in* 1904.)

	Phosphoric acid (P_2O_5).	Silica.	Ferric and aluminic oxids.
Sulfate of ammonia plats, unlimed...........	9	16	75
Sulfate of ammonia plats, limed.............	13	3	72
Nitrate of soda plats, unlimed...............	10	16	68
Nitrate of soda plats, limed.................	13	10	76

It may be seen that the ingredients mentioned above, constitute from 88 to 100 per cent. of the ash constituents associated with the extracted humus. The amount of phosphoric acid is greater in the ash from the limed plats than from the unlimed ones, whereas, in the case of silica, the reverse is true. This results in a wide difference in the relation of silica and phosphoric acid in the ash associated with the humus from the limed and from the unlimed plats.

The high percentage of ferric and aluminic oxids (apparently mostly ferric oxid) in the ash associated with the humus of these soils indicates some intimate connection between the humus and iron. In order to ascertain to what extent iron and humus will combine, the following work was undertaken. Leaf mould which had accumulated upon a rock in the forest and was, therefore, fairly free from soil admixture was extracted with a 2.5 per cent. ammonia solution. Ferrous chlorid, made by digesting an excess of nails in hydrochloric acid with exclusion of air until action had ceased, was poured in excess into the ammonia extract. Nearly all of the iron was precipitated, and no additional humus could be thrown out of the filtrate by hydrochloric acid. The precipitate was digested in dilute hydrochloric acid and, after decanting the latter, was dissolved nearly completely in dilute ammonium hydroxid. The precipitate was again thrown out from the filtered solution, by hydrochloric acid. The digestion in the same, and subsequent treatment with ammonium hydroxid as just described, were repeated several times in an attempt to remove such iron as was not intimately combined with the humus. The flasks in which the digestions were conducted were kept filled, and air was excluded quite generally, so that at least most of the iron should remain in the ferrous condition. The precipitate was finally washed practically free from acid, and dried under 90° C in a partial vacuum. The dried material was black and had a vitreous luster. It contained 11 per cent. of ash which had the following percentage composition: silica, 7; phosphoric acid, 10; ferric oxid, 83. It should be recognized

that the composition of material prepared in this way will vary considerably with the extent of the digestion in hydrochloric acid.

The readiness with which iron in the ferrous condition combined with the humus in considerable quantity, and the quite generally asserted poisonous effects upon plant growth attributed to ferrous compounds, impress the thought that the less-productive, unlimed soil may contain iron in ferrous combinations with the humus.

The concentrated aqueous extract of the soil exhibited no reaction for iron with either potassium ferro- or ferricyanid. It is possible, however, that ferrous compounds may be present in the soil which are not readily soluble in water but still have a detrimental influence on the growth of plants. Koenig* mentions the different effect of ferrous oxid upon plant growth depending upon whether it is combined with silica, carbonic acid, sulfuric acid, or humous material. In the same connection a method is outlined for determining the amount of ferrous oxid in soils containing moderate amounts of humus. It consists essentially of digesting a soil in dilute sulfuric acid upon a water-bath, in an atmosphere of carbon dioxid, and titrating the solution with potassium permanganate. It was recognized that the results may be too high in the case of soils rich in humus, owing to the presence of organic matter. The soils from the unlimed and limed sulfate of ammonia plats were subjected to the above method for determining ferrous oxid. There was no satisfactory end-point upon titrating with permanganate. Even after a somewhat permanent pink color was obtained, a drop of the solution reacted at once with potassium-ferricyanid as though ferrous compounds were still in solution. It is not improbable that the organic matter in the solution interfered with the complete oxidation of the ferrous compounds. The titrations were somewhat easier to accomplish when an excess of the permanganate was added, and the same was titrated back with ammonium ferrosulfate, but they were still very uncertain. A fairly satisfactory end-point was finally secured, however, by using potassium dichromate as an oxidizer instead of the permanganate,

* Untersuchung landwirtschaftlich u. gewerblich wichtiger Stoffe, Berlin, 1898, p. 43.

and testing a drop of the solution from time to time with potassium ferricyanid until no color was produced. The amount of ferrous oxid determined by this modification equalled 0.46% of the air-dry unlimed soil, and 0.50% of the limed soil. It seems as though very little significance should be attached to the presence of iron in the ferrous condition when organic matter and ferric compounds exist in the same solution, as was the case in the dilute sulfuric-acid extract of the soil, owing to the possibility of the ferric compounds being reduced by the organic matter. The most that can be said is that this method affords no indications of the presence of a larger amount of ferrous compounds in the unlimed than in the limed soil. It is probable, however, that considerable amounts of iron are combined with the organic matter in such a way that it could not be brought into solution by the sulfuric-acid digestion. The failure of dilute hydrochloric acid to remove the iron from the artificially prepared humus mentioned above would indicate this. No reliable method suggests itself for determining all of the iron in the particular state of oxidation in which it is present in soils containing considerable organic matter, owing partly to the possibility that some iron in the ferric condition may be reduced by the organic matter to the ferrous condition during the analysis. If a method were available, it might be found that considerable iron in the ferrous condition is in combination with the organic matter in the unlimed soil in a form which is detrimental to plant growth. The iron which is present in an ammoniacal extract of humus is not thrown out of solution by a soluble phosphate nor by ammonium sulfid. This may be because it is combined with humous material to form a complex ion, and therefore fails to conform with the usual behavior of its simple ion.

SUMMARY.

Since 1893 two of the permanent experimental plats upon the Station plain have received equal amounts of nitrogen annually in sulfate of ammonia, and two others in nitrate of soda. About 3.7

tons of air-slaked lime have been applied in all to one of the plats receiving sulfate of ammonia, and to one of those receiving intrate of soda. Equal amounts of muriate of potash and dissolved bone-black have been added annually to each plat.

The amount of humus is now less in the limed than in the unlimed plats.

The amount of free humus is likewise less in the limed plats.

A smaller part of the humus is present as free humus in the limed plats.

The loss by igniting the oven-dry soil was somewhat less from the samples of the limed plats than from the unlimed ones.

The total nitrogen in the limed plat to which nitrate of soda is applied is less than the amount common to the other three plats.

In the case of the unlimed plats the one to which sulfate of ammonia has been added would require much more lime to neutralize it, according to the lime-water test, than the one which has received nitrate of soda. Upon the same basis, no further application of lime would be required for the limed plat to which nitrate of soda has been added, although the limed plat receiving sulfate of ammonia is still somewhat acid.

Most of the ash left upon destroying the separated humus and free humus by ignition is composed of iron and aluminum oxids, phosphoric acid, and silica.

In the case of the ash remaining from the free humus, that from the limed soils contained larger percentages of phosphoric acid and smaller percentages of silica than that from the unlimed soils.

Surprisingly large amounts of iron were found in the ash left from the ignition of the humus and free humus. The iron in the ammoniacal solutions of humus could not be thrown out by certain of the ordinary precipitants.

An artificial product made by precipitating the humus from an ammoniacal extract of leaf mould, by means of ferrous chlorid,

contained in its oven-dry condition 11 per cent. of ash, of which 83 per cent. was ferric oxid; the remainder being phosphoric acid and silica.

If a satisfactory method were available for determining the state of oxidation of the iron associated with the organic matter of soils, it is not improbable that, where the productiveness of a soil is markedly increased by liming, the amount of iron in the ferrous condition would be found to have been decreased.

THE PHOSPHORIC ACID REMOVED BY CROPS, BY DILUTE NITRIC ACID AND BY AMMONIUM HYDROXID FROM A LIMED AND UNLIMED SOIL RECEIVING VARIOUS PHOSPHATES.*

B. L. HARTWELL AND J. W. KELLOGG.†

General Plan of the Field Experiment.

The experiment which rendered advisable the work herein recorded was begun at this Station in 1894, to determine the comparative manurial value of a number of different phosphatic materials. Some of the crop results have been reported, from time to time, in the publications of this Station, by the different persons having the experiment in charge.‡ The experiment comprises twenty two-fifteenth-acre plats, all of which have received annually liberal amounts of potash and nitrogen. The plats are grouped in pairs, one plat of each pair having received air-slaked lime and the other having received none. One pair has received no phosphatic manure since the experiment was begun; while the remaining pairs have each received a different phosphatic manure.

During the first years of the experiment an equal money value of the different phosphatic manures was applied to all of the plats; but later applications were made in such amounts that the total

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* To be presented in abstract at the annual convention of the Association of Official Agricultural Chemists, to be held in Washington, D. C., in November, 1905.

† The authors are indebted to Dr. H. J. Wheeler for many kindly criticisms of the manuscript.

‡ See Ann. Rpt. R. I. Agr. Expt. Sta., 1894, p. 122; Ann. Rpt., 1896, p. 227; Ann. Rept., 1897, p. 394, and Bull. 58, 1899

quantity of phosphoric acid applied to each of the phosphate plats from the beginning of the experiment was the same. It was thought when the spring application of 1899 had been made that this equalization of the amount of phosphoric acid received by each plat had been accomplished, but an error was subsequently discovered which made it necessary to apply more phosphoric acid to certain plats, so that it was not until the application was made in the spring of 1902 that each of the phosphate plats had really received, since the beginning of the trial, the same amount of phosphoric acid, namely, 98.48 pounds, regardless of its form. No phosphatic manures have been applied since to any of the plats.

The Soil Samples.

In the spring of 1903, a year having elapsed since any of the plats had received phosphoric acid, it was thought advisable to collect samples of the soil for certain chemical work designed to aid in a study of the effects upon the soil of the various applications. Accordingly, in the latter part of June samples of the soil of each plat were taken. Of the many crops which had been planted across the plats the garden peas and oats were the only ones which had made any considerable growth, and had begun to feed upon the soil to any great extent.

Borings, approximately eight inches deep, which extended to the subsoil, were made at twenty-six different places in each plat, care being taken to make the borings at the same relative places so that any influence exerted upon the soil by the various plants which had at times been grown across the plats would be shared as equally as possible by all of the samples. The soil secured by the various borings from a given plat was air-dried and mixed, and a portion of the same which passed a two-millimeter sieve was used for all of the determinations recorded in this article. While the area devoted to the experiment is in general very level, there are individual plats which have at some time been slightly affected by washing, resulting in a greater or lesser proportion of fine gravel. There was

very little of this gravel which was too coarse to pass a three-millimeter sieve. The amounts of material too coarse to pass a sieve with two-millimeter holes, which was used in preparing the samples for analysis, is given below for the various plats.

Plat No.	**51.**	**53.**	**55.**	**57.**	**59.**	**61.**	**63.**	**65.**	**67.**	**69.**
Per cent. of gravel	7	5	4	5	6	5	4	6	4	3
Plat No.	**52.**	**54.**	**56.**	**58.**	**60.**	**62.**	**64.**	**66.**	**68.**	**70.**
Per cent. of gravel	11	5	6	6	5	6	5	9	13	8

CHARACTER OF THE SOIL.

The soil* upon which the experiment is conducted is composed of glacial drift of granitic origin. It is underlaid by yellow silt loam resting upon alternating layers of gravel, sand, and silt, which furnish good natural drainage. The water table is from ten to fifteen feet below the surface. Hot hydrochloric acid of 1.115 specific gravity dissolves approximately 4.5 per cent. of aluminic oxid, 3.5 per cent. of ferric oxid, 0.6 per cent. of calcium oxid, and 0.15 per cent. of phosphoric acid. Only about 0.02 per cent. of calcium oxid was extracted by carbonated water. It contains from three to four per cent. of humus, of which considerable may be dissolved directly by ammonium hydroxid without previous extraction with dilute acid. The soil reacts strongly acid to litmus paper and fails to produce satisfactory yields, in the case of many crops, without an addition of lime or other alkaline materials.

COMPARATIVE YIELDS FROM THE VARIOUS PLATS.

The relative yields, in a green state, of certain of the crops grown across the plats in 1903, one year after the last application of phosphoric acid, are given below. These crops are selected, from the various ones planted in that year, because they grew fairly well, even upon the unlimed plats, and because they will be referred to later in connection with their phosphoric acid content.

* Classified as Miami Silt Loam, by the Bureau of Soils, U. S. Dept. of Agr.

The turnip crop, which will be considered later, made but a comparatively poor growth upon the unlimed series of plats.

Relative Yields in 1903 *from the Different Plats, Compared with that of the Unlimed Check Plat Taken as* 1.0.

KIND OF PHOSPHATE.	Golden German Millet.		Japanese Barnyard Grass. (Panicum Crus-galli.)		Oats.	
	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.
Dissolved bone-black........	2.9	3.2	3.0	4.0	3.4	3.8
Dissolved bone.............	2.9	3.5	4.6	4.5	4.3	4.6
Dissolved phosphate rock....	3.0	2.8	4.0	4.6	4.4	4.5
Finely ground bone..........	3.1	3.3	3.9	4.3	4.4	4.8
Slag meal (Thomas phosphate).................	2.8	3.0	3.7	4.0	4.5	4.5
Floats (undissolved phosphate rock)............	2.9	3.3	3.4	3.6	3.2	4.1
Raw Redonda phosphate....	2.2	2.6	2.8	3.5	2.1	2.9
Roasted Redonda phosphate.	2.4	3.2	3.0	4.2	1.9	4.2
No phosphate..............	1.0	2.5	1.0	2.6	1.0	2.6
Double superphosphate.....	1.6	3.2	1.1	3.9	1.8	4.2

No attempt should be made to draw conclusions from the above results, except in a very general way, as to the comparative value of the different phosphates, even for the crops mentioned here; for only from eight to sixteen rows, twenty-four feet long, were grown in each case.

It would be necessary to compare results of more than one season and to study slight physical inequalities in the plats before one would be in a position to consider the comparative merits of those phosphates which are of approximately the same crop-producing value. For the purposes of this article, detailed consideration of the individual plats is unnecessary, as attention will be more largely directed to certain groups of plats which show quite different degrees of productiveness.

THE RELATIVE ACIDITY OF THE DIFFERENT PLATS.

It may be seen from the preceding table of relative yields that the crops were nearly always larger upon the limed plats, even though the plants considered grew quite well upon the unlimed soil, as compared with certain others which were tested. It seemed, therefore, that determinations of the acidity of the several plats might throw light upon the question as to which kind of phosphate is the most assimilable, since differences in the acidity of the soil, resulting from the varying effects of long-continued applications of the different phosphates, might exert as great an influence upon the growth of some plants as the differences in the assimilability of the phosphorus in certain phosphates.

The acidity of the soil of the different plats was determined by the lime-water method,* which consists in brief of adding a certain amount of water and of a standard lime-water to the soil, and evaporating to dryness over a water-bath. The residue is then transferred with 100c.c. of water to a flask, shaken frequently, allowed to subside over night, and 50 c.c. of the supernatant liquid evaporated with phenolphthalein. According to whether the pink color does or does not appear before a volume of 5 c.c. has been reached, the analyst knows if too much or too little lime-water has been added to produce neutrality, and is guided thereby in succeeding attempts to secure neutralization with different amounts of lime-water. It was found that variations in the shaking and time of standing had considerable influence upon the results, and the details were therefore kept uniform in this work.

*Veitch: Jour. Amer. Chem. Soc. 26, (1904), 661.

Amount of Calcium Oxid Required to Neutralize the Acidity of the Air-dry Soil Which had Passed a 2 m.m. Sieve.

KIND OF PHOSPHATE.	UNLIMED.		LIMED.	
	Plat.	Calcium oxid required to neutralize.	Plat.	Calcium oxid required to neutralize.
		%		%
Dissolved bone-black	52	0.17	51	0.09
Dissolved bone	54	0.20	53	0.15
Dissolved phosphate rock	56	0.20	55	0.16
Finely ground bone	58	0.15	57	0.13
Slag meal	60	0.11	59	0.08
Floats	62	0.17	61	0.12
Raw Redonda phosphate	64	0.16	63	0.08
Roasted Redonda phosphate	66	0.18	65	0.17
No phosphate	68	0.19	67	0.12
Double superphosphate	70	0.24	69	0.19

The limed plats received air-slaked lime at the rate of one ton per acre in 1894, and a second ton April 28, 1903. When the soil samples were taken, two months later, there were small particles of the lime which had become carbonated and which were easily visible. Apparently there were no particles too small to be so discerned, for examination under the microscope revealed no effervescence with hydrochloric acid treatment unless particles visible to the unaided eye were present. These particles were easily broken up and must be considered quite assimilable, for upon other plats of similar soil, which were examined two years after liming, no such particles were present. It is evident, therefore, that a method which shall determine the additional amount of lime required to complete the neutralization of a recently limed soil, such as represented by the samples of limed soil under discussion, should account for any particles of carbonated lime which may be present. The lime-water method failed to do this, at least completely, for such particles were always present in the limed samples after they had been subjected to this method for determining their acidity.

This explains in some measure why there was not a greater difference in acidity between the plats which had received two tons of lime and the corresponding ones to which no air-slaked lime had been added.*

It may be seen by reference to the preceding table that considerable difference exists in some cases in the acidity of the soil of the different plats in both the limed and unlimed series. The plats which receive slag meal, for example, have a relatively low acidity, while the plats fertilized with double superphosphate are the most acid of them all. It is certainly evident that the acidity of the soil of the several plats is one of the factors to be considered before intelligent comparisons can be made of the relative assimilability of the phosphorus in the different phosphates.

THE EFFECT OF THE DIFFERENT PHOSPHATES UPON THE PHOSPHORIC ACID CONTENT OF THE CROPS.

In order to throw more light upon the question as to whether the percentage of phosphoric acid in the crop furnishes indications as to the assimilability of the phosphorus in the soil upon which the crop is grown, samples of a number of the crops grown across the phosphate plats in 1903 were taken and the phosphoric acid determined in them.

The oats were sampled July 27, "in the milk." As may be seen by reference to page 256, the oats made the best growth upon the limed series of plats; and as the conditions there seemed to be more congenial it was thought that the phosphoric acid determinations might be confined to the limed series. The relative yields as compared with the unlimed check plat taken as 1 ranged from 2.6 upon the limed check plat to 4.8 upon the limed plat receiving finely ground bone, and indicate a very marked difference in the assimilability of the phosphorus of the different phosphates in the limed

* An application of two tons per acre of air-slaked lime containing 75 per cent. of calcium oxid, is theoretically equivalent to 0.13 per cent. of the soil, accepting, arbitrarily, two and one-third million pounds as the weight of the air-dry soil per eight-inch acre.

series under consideration. The following determinations of phosphoric acid will show to what extent this difference conforms to the analysis of the crop.

Percentage of Phosporic Acid in the Dry Matter of Oats Cut "in the Milk," 1903.

Plat. (*Limed*).	Kind of Phosphate added to the Soil.	Phosphoric Acid.
51	Dissolved bone-black	0.549
53	Dissolved bone	0.633
55	Dissolved phosphate rock	0.518
57	Finely ground bone	0.590
59	Slag meal	0.560
61	Floats	0.518
63	Raw Redonda phosphate	0.462
65	Roasted Redonda phosphate	0.606
67	No phosphate	0.502
69	Double superphosphate	0.540

The largest crops of oats, namely, those from the plat receiving dissolved bone and from the one receiving finely ground bone, contained high percentages of phosphoric acid, namely, 0.633 and 0.590, respectively while the smallest crops, those from the check plat and from the plat receiving raw Redonda phosphate, contained only 0.502 and 0.462 per cent., respectively. The yields of oats in 1904, also, were much the smallest from the last-mentioned two plats, while the greatest yield was upon the plat supplied with dissolved bone, which in the preceding year produced a large crop containing the highest per cent. of phosphoric acid of all. On the other hand, the plat to which dissolved phosphate rock had been applied yielded much larger crops of oats, both in 1903 and 1904, than the plat which had received roasted Redonda phosphate, although the per cent. of phosphoric acid in the oats in 1903 from the former plat was only 0.518 as compared with 0.606 from the latter. This resulted in the actual removal by the crop of a greater amount of phosphoric acid per acre in the case of the smaller crop.

Percentage of Phosphoric Acid in the Dry Matter of Japanese Barn-yard Grass (Panicumcrus-galli) cut just Before the Plants were Ready to Drop Their Seeds, 1903.

Plat. (*Limed.*)	KIND OF PHOSPHATE ADDED TO THE SOIL.	Phosphoric Acid.
59	Slag meal	0.384
61	Floats	0.354
63	Raw Redonda phosphate	0.310
65	Roasted Redonda phosphate	0.360
67	No phosphate	0.328

With this plant, as with the oats, the smallest yields and the smallest percentages of phosphoric acid in the crops are in the cases of the check plat and the one receiving raw Redonda phosphate. The percentages of phosphoric acid in the crops from the other three plats here mentioned, however, do not differ in the same direction with the relative yields as given on page 256; for example, the largest yield from the five plats was from the one which had received roasted Redonda phosphate, although the crop from this plat did not contain the greatest percentage of phosphoric acid.

Percentage of Phosphoric Acid in the Dry Matter of German Golden Millet cut When the Seeds were Formed, but Still Green, 1903.

Plat. (*Limed.*)	KIND OF PHOSPHATE ADDED TO THE SOIL.	Phosphoric Acid.
59	Slag meal	0.411
61	Floats	0.335
63	Raw Redonda phosphate	0.244
65	Roasted Redonda phosphate	0.355
67	No phosphate	0.306

The order of the plats upon which the crops with increasing phosphoric acid content occur is the same with the millet as with the panicum crus-galli. The order of the yields upon the best three

plats, however, is different for the two crops. Upon these three plats the percentage of phosphoric acid in the millet *decreased* with the *increase* of crop.

Relative Yields in 1903 *of Purple-Top, Strap-Leaf, Turnip Plants From the Different Plats, Compared with that of the Limed Check Plat Taken as* 1.0.

Plat. (*Limed.*)	KIND OF PHOSPHATE.	Relative yields of green material compared with Plat 67 as 1.0.	
		Roots.	*Tops.*
51	Dissolved bone-black	16.7	11.7
53	Dissolved bone	25.4	13.8
55	Dissolved phosphate rock	22.4	13.1
57	Finely ground bone	27.0	15.2
59	Slag meal	17.2	12.0
61	Floats	8.2	7.2
63	Raw Redonda phosphate	1.7	1.6
65	Roasted Redonda phosphate	7.8	5.4
67	No phosphate	1.0	1.0
69	Double superphosphate	22.5	12.6

It is evident from the relative yields given above that this kind of turnip is much more dependent upon readily assimilable phosphorus than the crops which have been heretofore considered; for the more available phosphates have increased the yield of roots more than twenty times that upon the check plat, and the yield of tops more than twelve times. In the cases of the millet, oats, and panicum, however, the yields upon the corresponding limed plats were in no case double those upon the limed check plat. It seemed reasonable, therefore, that there would be greater variations in the phosphoric acid content of turnips than of the other crops which have been considered, and determinations of the same which appear below were made in both the roots and the tops.

Percentage of Phosphoric Acid in the Dry Matter of the Turnip Roots and Tops, Sampled at the Time of Harvesting.

Plat. (*Limed.*)	KIND OF PHOSPHATE ADDED TO THE SOIL.	Phosphoric Acid.	
		Roots.	*Tops.*
51	Dissolved bone-black	0.673	0.610
53	Dissolved bone	0.837	0.726
55	Dissolved phosphate rock	0.716	0.624
57	Finely ground bone	0.866	0.833
59	Slag meal	0.741	0.647
61	Floats	0.526	0.471
63	Raw Redonda phosphate	0.450	0.312
65	Roasted Redonda phosphate	0.446	0.350
67	No phosphate	0.447	0.314
69	Double superphosphate	0.650	0.585

The percentages of phosphoric acid in both the roots and tops increase in practically the same order from plat to plat, so that a consideration of the percentages of the same in the tops will serve also for the roots. The growth upon the plat to which raw Redonda phosphate had been added and upon the check plat was extremely poor, due to lack of assimilable phosphoric acid, and the percentage of phosphoric acid in the same is only about 0.31. The plats which had received roasted Redonda phosphate and floats yielded only very moderate-sized crops, although much larger than the two plats mentioned above. The crop from the floats was a trifle the greater, and the percentage of phosphoric acid in the tops, 0.471, represents a considerable increase over that in the tops from the poorest two plats. While there is a marked increase in the percentage of phosphoric acid in the crops from the plats producing the larger yields, yet the yields and the amounts of phosphoric acid in the crops do not increase strictly in the same relative order from plat to plat. The largest two crops, however, those from finely ground bone and dissolved bone, contained noticeably more phosphoric acid than any of the others, namely, 0.833 and 0.726 per cent., respectively.

The range in the percentage of phosphoric acid is from 0.31 to 0.83 in the tops and from 0.45 to 0.87 in the roots, and is very striking as compared, for example, with the range of from 0.46 to 0.63 only in the oats grown at the same time across the same plats.

Plants similar to the turnip, having a poorly developed system of feeding-roots, and being very dependent upon having their phosphoric acid in a readily assimilable form, and, furthermore, containing a large amount of sap and a correspondingly large percentage of ash in the dry matter, are apparently more suitable for furnishing indicacations, from their analysis, of the amount of readily available phosphorus in the soil, than plants similar to the oat in feeding power. The observations made by A. D. Hall* upon the Rothamsted experiments are of a similar nature, the root crops having been found to be very sensitive to a lack of mineral plant foods in the soil, while cereals were comparatively indifferent. He states that "the phosphoric acid requirements are well indicated by the composition of the ash of unmanured swedes."

The phosphate plats are now in grass for the purpose of introducing fresh organic matter; but it is hoped that they may be again devoted to miscellaneous crops in a few years, so that work may be undertaken, with the turnip, similar to that which appears so promising from a single year's experience.

THE EFFECT OF LIME UPON THE ASSIMILABILITY OF SOIL PHOSPHORUS.

The crops herein considered have been larger, almost without exception, upon the limed plats than upon the corresponding unlimed ones, the turnips even failing to make a satisfactory growth upon the unlimed plats. According to the lime-water method the applications of lime have reduced the acidity of the soil to some extent (see page 258). Numerous experiments at this Station upon soil of the same general character as that under discussion have shown that most agricultural plants produce larger crops when air-slaked lime or other alkaline material has been applied, even though liberal

* Jour. Agr. Sci. I. 65 (1905).

amounts of phosphoric acid and other plant foods, in assimilable forms, have been added.

It is important to consider in this connection, apart from the physical effect, whether the increased growth upon the limed series of plats is due mainly to a reduction in the acidity of the soil or in a considerable part to an increased development of assimilable phosphorus. If the application of air-slaked lime has no effect upon the supply of available phosphorus, but simply renders the reaction of the soil more suitable for the growth of certain plants, then the yield upon the slag-meal plat, for example, might be relatively larger, on account of the basic action of this material, than if the amount of assimilable phosphorus it contained was the only influencing factor; and the percentage of phosphoric acid in the crop might be correspondingly smaller. On the other hand, if a reduction of the acidity of the soil renders the phosphorus of the soil more assimilable, then the percentage of phosphoric acid in the crop from the less acid plats, other things being equal, might be increased.

Certain results follow which indicate that the lime may tend to increase, in some cases, the amount of available phosphorus. The crop of turnip roots from the limed plat which had received finely ground bone was 62 per cent. greater than from the corresponding unlimed plat, and the per cent. of phosphoric acid in the dry matter of the roots was 0.866 from the limed plat and 0.804 from the unlimed one. Again, the increase in the crop of turnip roots from the limed plat to which slag meal had been added was 34 per cent. as compared with the unlimed plat, and the phosphoric acid in the dry matter of the roots was 0.741 per cent. from the limed plat and 0.708 per cent. from the unlimed one. These increases in the percentage of phosphoric acid in the turnip roots grown upon the limed plats furnish some evidence that more of the phosphorus in these plats was assimilable.

In order to secure a hint as to the action of lime upon the phosphorus of the soil of the Station plain, a sample was taken from plats contiguous to those upon which the phosphate experiment is con-

ducted; this was air-dried for a few days and sifted through a millimeter sieve. The soil then required, according to the lime-water method, 0.20 per cent. of calcium oxid to neutralize it. Four 65-gram portions were weighed out; to one portion nothing was added; to the second 0.7429 gram of hydrated lime was added (about 10 tons per acre); to the third, 0.1486 gram of c. p. sodium nitrate and 0.1486 gram of c. p. potassium sulfate (about 2 tons each per acre); and to the fourth, 0.7429 gram of hydrated lime in addition to the same amount of sodium nitrate and potassium sulfate as was added to the third portion. After thorough mixing, each portion was placed upon a double filter in a funnel, covered with a piece of filter paper to prevent puddling, and leached at the same time as the others with 20 c. c. portions of distilled water until 250 c. c. of extract was obtained. The leaching was done during the business hours between the middle of the afternoon and noon of the following day. The extracts were perfectly clear. They were evaporated in porcelain dishes and the residues ignited. Upon ignition of the residues there was considerable evidence of organic matter in the cases of the limed portions. The acid extracts from the four residues were tested with molybdic mixture in the usual manner, the volumes being equal in all cases, so that the amounts of phosphoric acid from the original portions to which lime was added could be compared with those from the portions to which no lime was added without the necessity of making quantitative determinations of such small amounts. The relative amounts of ammonium phosphomolybdate, as indicated by color and precipitate, left no doubt about there being more phosphoric acid in the extracts from the portions to which the hydrated lime had been added than in the others. This difference was quite marked, both in the comparison upon the natural soil and when sodium nitrate and potassium sulfate had been added. The trial was carried through again subsequently with the same results. A blank determination was made with the sodium nitrate, potassium sulfate, and hydrated lime, but no phosphoric acid was obtained. The above results suggest that some of the benefit derived from

liming the Station soil is probably due to the liberation of an increased amount of phosphorus whenever there may be a lack of the same; and that a consideration of the availability of phosphorus in different phosphates, and of the percentage of the same in the crops, should be accompanied with a recognition of the varying effects of different phosphates upon the reaction of the soil.

THE EFFECT OF THE NITROGEN ASSOCIATED WITH BONE PHOSPHATES.

It may be seen by reference to pages 260 and 263 that the percentages of phosphoric acid in the crops from the plat which had received dissolved bone and from the one to which finely ground bone was added in the cases of the two crops analyzed, namely, oats and turnips, were greater, with one exception, than upon any other plats; the highest yields also were from these plats. Such a liberal amount of nitrate of soda was added annually to all of the plats that no deduction was made for the additional amount of nitrogen contained in the dissolved bone and finely ground bone. In view, however, of the large yields from these plats, nitrogen determinations were made in the turnip roots and tops from the same, and also from contiguous plats whose source of phosphorus contained no nitrogen. Had more nitrogen been found in the crops fertilized with the phosphates which had nitrogen accompanying them, namely, the bones, a hint would have been obtained that possibly the extra nitrogen played an important part, as plant food, in the production of the greater crops. Instead of there being more nitrogen, however, there was generally less, as shown below.

Percentage of Nitrogen in the Dry Matter of the Turnip Roots and Tops.

Plat. (*Limed.*)	KIND OF PHOSPHATE ADDED TO SOIL.	Roots.	Tops.
53	Dissolved bone	2.14	3.39
55	Dissolved phosphate rock	2.20	3.72
57	Finely ground bone	2.51	3.70
59	Slag meal	2.85	4.06

The Phosphorus Associated With the Organic Matter of the Soil.

The field experiment under consideration furnished an exceptionally good opportunity for studying the solubility, in different solutions, of the phosphorus in the various plats, to ascertain if the amounts dissolved indicated to any extent the relative productiveness of the plats.

A large part of the phosphorus in the soil where the experiment was conducted is associated with the humus. The *total* phosphoric acid was determined in soil from four different experimental plats upon the plain (Nos. 23, 25, 27 and 29), after igniting the soil to render any phosphorus, which might be associated with the humus, soluble in acid and then digesting in strong hydrochloric acid. The insoluble silicious material was treated with sulfuric and hydrofluoric acids to volatilize the silica, and the residue dissolved in strong hydrochloric acid so that any phosphorus which might have formed insoluble combinations with the silicious material could be included with that from the first extraction. The average of the four determinations was 0.26 per cent. of phosphoric acid. Had the solutions been prepared by the usual digestion in hydrochloric acid of 1.115 specific gravity, without previous ignition, this amount would undoubtedly have been considerably less; for it has been repeatedly shown that, in soils having a large proportion of their phosphorus in organic combinations, a considerable amount fails to be obtained by simply digesting in hydrochloric acid. The phosphoric acid which was associated with the total humus of the same samples averaged 0.13 per cent., or one-half of the total amount in the soil.

Snyder says* "humic phosphoric acid is * * * one of the most valuable forms of available phosphoric acid," and it certainly seems reasonable that a considerable portion of the assimilable phosphorus in certain soils is developed from the humates. The weak acid solutions, however, which have been found in many instances to dissolve from

* Bul. 53, Minn. Exp. Sta., page 32.

soils amounts of phosphorus bearing similar relations to the productiveness of those soils, exert practically no solvent effect upon the phosphorus associated with the humus. Snyder,* for example, digested a soil for three months with a one per cent. citric-acid solution, without decreasing the amounts of phosphorus associated with the humus and with the precipitated humus.

The greater number of the attempts which have been made in the past to determine the assimilable mineral ingredients of soils have been carried out with solvents which had little effect upon the portions of those ingredients which are combined with organic matter although much evidence has been obtained that some relation exists between the productiveness of certain soils and the mineral ingredients associated with the humus which are brought into solution by alkaline solvents attacking the organic matter. The Hilgard method for soil analysis includes the determination of the phosphoric acid in the ash of the humus, and it is reported as "soluble phosphoric acid." Hilgard says, "a very striking agreement with actual practice is often found in making this determination."

Huston†, after working with an ammonium oxalate solution supplemented on the one hand by ammonia and again by acid, with citric acid alkaline and neutral ammonium chlorid, and with ammonia of 0.96 sp. gr. at room temperature, decided upon the latter as giving promising results in connection with the determination of assimilable phosphoric acid, and stated that "the results clearly distinguished the lands poor in phosphoric acid from those known to be well supplied with available phosphoric acid." More recently Veitch‡, in connection with the use of $\frac{n}{100}$ hydrochloric acid, remarks that the phosphorus of organic matter is apparently but little affected by this acid, and states: "it appears desirable to study the solvent effect of more concentrated acids, at the same time endeavoring to reach the phosphorus in organic combination."

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* Bul. 65, Minn. Exp. Sta., page 63.

† Bul. No. 49, Div. of Chem. U. S. Dept. of Agr., (Proc., A. O. A. C. '96) page 95.

‡ Bul. No. 81, Bur. of Chem. U. S. Dept. of Agr., (Proc. A. O. A. C. '03) page 138.

The Relative Amounts of Phosphorus Extracted by Nitric Acid and by Ammonium Hydroxid.

To gain some idea of the relative amounts of phosphorus in the soils in question which are soluble in dilute acid and in ammonium hydroxid, a few preliminary tests were made. The conditions of digestion were uniform in all of the work recorded in the succeeding pages, and were as follows: 200 grams of the air-dry soil which had passed a two-millimeter sieve were added to two liters of the solvent contained in a two-and-one-half liter, glass-stoppered bottle, after the temperature of the solution had been brought to 40° C. by immersion in a water-bath. The temperature of the solution was maintained at from 40° to 44° for five hours, agitating the bottle every half-hour by inverting it twelve times. The solution was then decanted through a filter, and from 1,700 to 1,900 c.c. of the clear filtrate evaporated for the gravimetric determinations. The silica which had been rendered insoluble was volatilized with hydrofluoric acid so that any phosphorus which might have been retained by it was secured. The ammonium phosphomolybdate was reprecipitated to secure a better separation from the iron and aluminum in the cases of digestion with acid.

Samples of soil from four of the limed plats, Nos. 55, 61, 63, and 67, were digested with $\frac{n}{5}$ nitric acid and the percentages of phosphoric acid in the extract were, respectively, 0.0140, 0.0160, and 0.0144 for the first three, the average being 0.0146. The fourth solution was lost. The residues from the above extraction were washed with distilled water until the same remained neutral and then digested with $\frac{n}{5}$ ammonium hydroxid. The percentages of phosphoric acid obtained by this extraction were, respectively, 0.0774, 0.0953, 0.0796, and 0.0788, or an average of 0.0828. That is, less than one-fifth as much phosphoric acid was obtained by extracting the soil with $\frac{n}{5}$ nitric acid as was obtained by a subsequent extraction with the same strength of ammonium hydroxid. Determinations with $\frac{n}{25}$ solutions were made upon the same samples in the same manner as above.

The percentages of phosphoric acid dissolved by the $\frac{n}{25}$ nitric acid were, respectively, 0.0024, 0.0039, 0.0006 and 0.0017, or an average of 0.0022; and the subsequent extraction with $\frac{n}{25}$ ammonium hydroxid gave, respectively, 0.0312, 0.0394, 0.0254, and 0.0310 per cent. of phosphoric acid, an average of 0.0315 per cent., or more than fourteen times as much as was dissolved by the preliminary extraction with the acid. These results indicate that dilute alkaline solutions dissolve much more phosphorus from the soils in question than dilute acid of the same strength.

To ascertain the action of dilute ammonium hydroxid upon the soil not previously extracted with nitric acid, and to secure some hints as to the most desirable strength to use in an attempt to determine the more easily attacked phosphorus associated with the organic matter, soil from plats 54 and 64 (unlimed) were digested directly with $\frac{n}{5}$ ammonium hydroxid; 0.0395 and 0.0314 per cent., respectively, of phosphoric acid were obtained. These amounts, while differing in the same direction as the relative productiveness of the two plats, are too nearly alike to be of service in this connection, for the quantity of oats produced in 1903 was about twice as large upon the former plat as upon the latter. Furthermore, the percentage of phosphoric acid dissolved was too great to be considered as representing the assimilable portion. Soils from two plats, Nos. 56 and 68, upon which the relative yields of oats were as three to one in 1903, were next digested directly with a weaker solution of ammonium hydroxid, $\frac{n}{25}$, with the result that 0.0184 per cent. of phosphoric acid was extracted from the former and 0.0250 per cent. from the latter, or in reverse order to the yield of oats. Here again the amount of phosphoric acid dissolved is quite large, and a few preliminary determinations were made, using $\frac{n}{100}$ ammonium hydroxid, which showed sufficient agreement with crop results to warrant other determinations of the amount of phosphoric acid dissolved by this strength of ammonium hydroxid. The filtrates from this digestion were alkaline to methyl orange, and nearly neutral to litmus. The results are recorded in the following table:

Per Cent. of Phosphoric Acid Extracted by $\frac{n}{100}$ Ammonium Hydroxid.

Kind of Phosphate added to the Soil.	Unlimed.	Limed.
Dissolved bone	0.0040	0.0036
Slag meal	0.0031	....
Floats	0.0044	0.0038
Raw Redonda phosphate	0.0030	0.0018
Roasted Redonda phosphate	0.0054	0.0032
No phosphate	0.0068	0.0033

There is no general agreement between the above results and the productiveness of the various plats. The amount of phosphoric acid dissolved from the soil of the unlimed check plat is noticeably high. The percentage of phosphoric acid removed from the unlimed soils by the ammonium hydroxid is always greater than from the corresponding limed ones. The humus of the unlimed soils was likewise always dissolved to a greater extent by the direct treatment with the ammonium hydroxid without the previous extraction with acid as required in total-humus determinations.

It has been the general experience at this Station that liming decreases the amount of so-called free humus, *i. e.*, the portion directly soluble in ammonium hydroxid; in fact, the intensity of the dark extract by this solvent has come to be regarded as a suggestion of the amount of lime desirable to apply. It was not known, however, to what extent the phosphorus was associated with this particular portion of the humus. The amount of humus directly extracted by the $\frac{n}{100}$ ammonium hydroxid from five of the limed plats varied between 0.337 and 0.363 per cent., with an average of 0.350; the variation in the case of the corresponding unlimed plats was from 0.359 to 0.399 per cent., with an average of 0.378. It is an interesting fact in this connection that not only was there more humus directly soluble in $\frac{n}{100}$ ammonium hydroxid from the unlimed than from the limed plats, but that the percentage of associated phosphoric acid in the humus was also greater in each of the five cases where comparisons were made.

THE SOLVENT ACTION OF DILUTE ACID UPON THE SOIL PHOSPHORUS.

C. C. Moore* attempted to find a strength of hydrochloric acid which would remove approximately the same amount of phosphoric acid and potash from a soil as one crop of oats grown in pots. The conditions finally adopted by him for the extraction were as follows: 200 grams of soil; one liter of acid of such strength that it would be $\frac{n}{200}$ to methyl orange at the end of the digestion; a temperature of 40° C; digestion for five hours in a shaking machine. A preliminary digestion with a small amount of soil, using methyl orange as an indicator was carried out to ascertain what strength of acid was necessary at the beginning of the digestion in order to have $\frac{n}{200}$ acid at the end. This investigation was very comprehensive, including a large number of soils, both virgin and cultivated, from widely different localities. It seemed that our phosphate experiments afforded an excellent opportunity for testing the capabilities of this method, in the case of fertilized soil, for determining the amounts of assimilable phosphoric acid in the various plats, especially as young oat plants were growing upon the plats at the time the soil was sampled, and the phosphoric acid removed by the crop could be compared with that removed by the $\frac{n}{200}$ acid. It should be recalled, in this connection, that the plats were liberally fertilized with nitrogen and potash, so that the yield would be expected to depend upon the amount of phosphoric acid which the plants were able to secure from the various phosphates, and also that no phosphoric acid had been applied to any of the plats since the year preceding the one in which the samples of soil were taken.

The Bureau of Chemistry of the Department of Agriculture at Washington kindly consented to determine the phosphoric acid in the soils by the $\frac{n}{200}$ hydrochloric-acid method, as the Rhode Island Station was not equipped with a shaking machine and constant temperature oven, which would enable us to follow the method under the same conditions worked out by Moore at Washington. Our thanks

*Jour. Am. Chem. Soc. 24, 79 (1902).

are rendered here for this assistance. Sub-samples of the soil, representing exactly the samples upon which the other chemical work herein recorded was done, were forwarded to the Bureau of Chemistry. Circumstances prevented the Bureau of Chemistry from making the determinations of phosphoric acid in all twenty of the samples, but fortunately the ones upon which the determinations were made were from plats Nos. 51 to 60, inclusive, and represented the ones to which some of the best forms of phosphates had been added the year previously, viz.: dissolved bone-black, acid phosphate, dissolved bone, finely ground bone, and slag meal, with and without lime. Excellent crops of oats were produced upon these plats, especially upon those to which lime was added, during the season of 1903, at the beginning of which the soil samples were taken, and again in 1904 without further addition of phosphoric acid. Nevertheless, Moore writes as follows concerning the soils: "I digested them in the equivalent of $\frac{n}{100}$ hydrochloric acid and got no phosphoric acid. I have stated that the suggested scheme of analysis was probably not applicable to fertilized soils inasmuch as the conditions are altogether changed." As the method gave *no* phosphoric acid in the samples representing the best plats, it of course was not adapted for determining differences in the amount of assimilable phosphorus in the plats under consideration. If the experience gained heretofore at Washington with pot culture regarding the ability of the oat crop and the $\frac{n}{100}$ hydrochloric acid to remove similar amounts of phosphoric acid from virgin soils were to serve as a guide under our field conditions, it would have been expected that a comparatively liberal amount of phosphorus should have been dissolved, considering the excellent crops which were produced upon these plats and the large amount of phosphorus removed by them. Evidently the method is not adapted under our field conditions to soil such as the one which is receiving artificial manuring at this Station.

It was learned subsequently that phenolphthalein instead of methyl orange was incidentally used in these particular determinations, which

may explain, as indicated later, why no phosphoric acid was obtained.

F. P. Veitch, referee on soils for the Association of Official Agricultural Chemists in 1903, recommended the $\frac{n}{200}$ hydrochloric-acid method for co-operative work *without* increasing the strength of the acid by an amount equivalent to that neutralized by the soils, and later made the following statement in his report: "From these results it appears that the $\frac{n}{200}$ acid method when not corrected for basicity extracts less phosphoric acid from most soils than is removed by crops." He also points out the desirability of studying the solvent effect of more concentrated acid than the $\frac{n}{200}$

A few years ago $\frac{n}{5}$ hydrochloric acid was adopted provisionally by the Association of Official Agricultural Chemists "for the determination of the more active forms of the phosphoric acid in soils," and has not been abandoned since. Fifth-normal nitric acid has been shown to yield practically the same results, and determinations were therefore made with this solvent in samples from plats of widely different productiveness, namely: the limed plats to which dissolved phosphate rock, floats, and raw Redonda phosphate had been added. The relative yields of turnip roots from these plats in 1903 were 22.4, 8.2, and 1.7, respectively, compared with the check plat at 1.0. The percentages of phosphoric acid removed from the soil by the $\frac{n}{5}$ acid were 0.0140, 0.0160, and 0.0144, respectively. These amounts bear no relation to the crop results.

Preliminary trials with $\frac{n}{25}$ nitric acid, however, promised a little better, for the poorest two limed plats gave only 0.0006 and 0.0017 per cent. of phosphoric acid, whereas two plats of greater productiveness yielded 0.0024 and 0.0039 per cent. It was decided to make determinations in a number of the samples with this strength of acid, especially as a similar strength had been recommended by certain European chemists for such work. The initial strength of acid used upon all of the samples was the same; it was thought that this would admit of fair comparisons being made among the plats on the limed side; and again among those upon the unlimed side.

The results are given below:

Percentage of Phosphoric Acid Extracted by $\frac{n}{25}$ Nitric Acid.

KIND OF PHOSPHATE ADDED TO THE SOIL.	Unlimed.	Limed.
Dissolved bone	....	0.0029
Dissolved phosphate rock	0.0038	0.0024
Finely ground bone	0.0029	0.0026
Slag meal	0.0027	0.0017
Floats	0.0042	0.0039
Raw Redonda phosphate	0.0020	0.0006
Roasted Redonda phosphate	0.0038	0.0014
No phosphate	0.0052	0.0015

It may be readily seen that the first column of figures throws no light upon the amount of assimilable phosphoric acid in the unlimed plats. (Reference should be made to page 256 for the relative yields of certain crops upon the various plats.) The check plat gave the largest percentage of any, 0.0052, and produced the smallest crop. The plat receiving roasted Redonda phosphate gave only a fair crop compared with the first three which are accompanied above by the phosphoric acid percentages in the "unlimed" column, and yet as large an amount of phosphoric acid was obtained from it as from the first of the three plats just mentioned, and larger than from the two others.

With the limed plats there is a somewhat better agreement. (Reference may be made, also, in this case to the relative yields of turnips from these plats given on page 262, as this crop grew normally upon the limed plats when sufficient assimilable phosphorus was present.) The last three percentages in the "limed" column are the smallest, and they are from the poorest plats; but the plat to which floats had been added previously gave only a medium crop, although the percentage of phosphoric acid, 0.0039, is the largest from any of limed plats. It is possible that the acid was more largely neutralized in the case of the sample from the plat receiving slag meal,

owing to the alkaline nature of this material, and that the percentage of phosphoric acid, 0.0017, is on this account lower than from the three others above it, with which it should be classed from the standpoint of crop production. Considering the relatively small difference in the amounts of phosphoric acid extracted by the $\frac{n}{25}$ acid from the poorest and from the best plats, as compared with the very large differences in the amounts removed by the crops, the method does not appear of much value for determining even the relative amounts of phosphoric acid at the disposal of the plants under the conditions of the experiment.

It may be seen from the foregoing table that the amount of phosphoric acid extracted was always greater from the unlimed than from the limed plats. In order to ascertain if this was probably due to the difference in the strengths of the acid at the end of the digestion, caused by the added lime, an attempt was made in two instances to so change the strength of the initial acid that the solutions after the digestion of the samples of the limed and corresponding unlimed soil would be of about the same acidity as shown by methyl orange.

The soil from the unlimed plat receiving roasted Redonda phosphate was accordingly digested with a weaker acid than the $\frac{n}{25}$, so that the solution at the end of the digestion was about the same as from the corresponding limed soil; with the result that the percentage of phosphoric acid was reduced from 0.0038 to 0.0015, or to practically the same as from the limed plat. In another instance, with the samples from the no-phosphate plats, the strength of the solution was increased in the case of the limed sample to make its final strength about the same as that from the unlimed one. The percentage was increased thereby from 0.0015 to 0.0035. This is less, to be sure, than was obtained from the corresponding unlimed soil, namely, 0.0052, but taken with the results given above, from the plats receiving roasted Redonda phosphate, indications are furnished that, with strict attention to the equalization of the acidity at the end of the digestion, practically the same amount of phosphoric acid would

have gone into solution from the corresponding limed and unlimed soils.

In a given series, limed or unlimed, there were some differences among the various plats in the final acidity of the solution when tested with methyl orange, and in view of the considerable effect of a change in the strength of acid upon the amount of phosphoric acid dissolved, as shown by the above results, notice was taken as to whether these differences might be the reason for the failure of the $\frac{n}{25}$ acid to remove amounts of phosphoric acid comparable with the crop production. It was found, however, that the differences were not sufficiently great nor in such a direction as could account for the lack of agreement with the crop results.

According to some investigators quite wide variations in the strength of dilute nitric acid have exerted very little effect upon the amount of phosphoric acid dissolved, the contention being that the dilute nitric acid acted principally upon the phosphates of the alkalies or alkaline earths, and that a very considerable increase in the strength of the acid could be made before the phosphoric acid in the more insoluble combinations with iron and aluminum would be attacked to any great extent. Moore's* results with dilute hydrochloric acid, however, show that with many soils no such uniformity exists in the amount of phosphoric acid dissolved. The results by T. Schloesing, Jr.,† in this connection are very interesting. He digested about 20 grams of soil in about one liter of dilute nitric acid of varying strengths for ten hours at room temperature, with constant agitation, and found that about equal amounts of phosphoric acid were dissolved from a given soil when the final acidity of the solution was anywhere between one and two parts of nitrogen pentoxid in ten thousand up to one part in a thousand. This latter strength equals about $\frac{n}{50}$ nitric acid. With this dilute acid scarcely any iron was brought into solution; but as the greater strength of acid was ex-

*Jour. Am. Chem. Soc. 24, 92, (1902.)

†Compt. Rend. Acad. Sci. Paris, 128, 1004 (1899), Abs. Centbl. Agr. Chem. 29, 79, (1900.)

ceeded the amount of iron increased and the amount of phosphoric acid no longer remained constant.

The final acidity of the solutions after digestion with $\frac{n}{25}$ nitric acid was in our case from $\frac{n}{50}$ to $\frac{n}{90}$ in round numbers, using methyl orange as an indicator, and $\frac{n}{26}$ to $\frac{n}{31}$ with luteol*, the acidity being somewhat less when the limed soil instead of the unlimed soil was digested. It is presumed that the indicator used by T. Schloesing, Jr., although not mentioned in the articles referred to, took into account simply the reduction in the acidity caused by the stronger bases in the soil, and that the final acidity of our solutions as determined by luteol would therefore furnish a better basis for comparisons. Viewed from this standpoint the final acidity where we used $\frac{n}{25}$ nitric acid was greater than that found, by T. Schloesing, Jr., to be capable of exerting a solvent action upon the iron compounds, although according to the acidity determined by methyl orange, our solutions were within the range of acidity found by him to give a constant amount of phosphoric acid and practically no iron. It should be recalled that our conditions for digestion and the proportion of soil to solvent were different from those of T. Schloesing, Jr., and that any comparisons made with results secured by this method should be viewed accordingly. Nevertheless, in view of the quite extensive work done by A. de Sigmond† with the Schloesing method, such comparisons seem warranted to a certain extent. T. Schloesing, Jr., extracted by this method from four different soils about 0.010, 0.018, 0.025, and 0.175 per cent. of phosphoric acid with nitric acid having a final acidity somewhat less than $\frac{n}{50}$. Sigmond under similar conditions, by the same method, secured only traces from two soils and percentages of phosphoric acid ranging from 0.013 to 0.159 in seven other soils, and finds, by comparison with results secured by the growth of plants in pots, that as a rule soils containing over about 0.075 per cent. of phosphoric acid soluble in the dilute

* It was found by trial with the soil solutions that the titrations with ammonia using luteol as an indicator were about the same as with potash using phenolphthalein, so that the former was used in our case for convenience.

†Ann. Sci. Agron. 16, II, 451, (1900.)

nitric acid were not benefited by phosphates, although it was not always true that soils yielding less than this amount were in need of phosphatic fertilizers.

The amounts of phosphoric acid secured by the Schloesing method of digestion from the soils considered above are, as may be noticed, much greater, as a rule, than were obtained by us from the soil of the phosphate experiment; for the maximum amount in our case was only about 0.005 per cent., while as a rule not more than 0.003 per cent. was secured. The percentages of combined ferric and aluminic oxids, however, obtained by us with $\frac{n}{25}$ nitric acid vary from 0.38 to 0.59 per cent. among the various plats, while the three soils in which T. Schloesing, Jr., determined the ferric oxid, obtained by digestion in nitric acid of about the same final acidity, contained only about 0.02, 0.05, and 0.01 per cent., or a tenth as much as our soil yielded. It is quite probable that the ferric oxid recorded by T. Schloesing, Jr., included also any aluminic oxid which may have been present, although this point is not discussed, for his main object in making this determination was to indicate at what strength of acid the phosphates which are more insoluble than the alkaline earth phosphates went into the solution, and the aluminum as well as the iron phosphates would be included in this class. It seems quite evident that the soil from our phosphate experiment yielded much more iron and aluminum and less phosphoric acid, to the action of dilute nitric acid, than those investigated by T. Schloesing, Jr.

As was stated before, the final acidity of the solution obtained by us by digesting the soil in $\frac{n}{25}$ acid was somewhat greater than recommended by T. Schloesing, Jr., in case he used an indicator similar to phenolphthalein, whereas if he used an indicator similar to methyl orange, our strength of acid was within the limits established by him. In order to be certain to have the amounts of iron and aluminum oxids secured by an acid within the same limits of strength as recommended by Schloesing, a few determinations were made of the amount dissolved by dilute nitric acid having an initial acidity of $\frac{n}{75}$. The *final* acidity by luteol varied from $\frac{n}{75}$ to $\frac{n}{125}$

among the four different plats tested, and was therefore within the limits fixed by Schloesing ($\frac{n}{50}$ to five or ten times this dilution) if viewed from the standpoint of this indicator. Even this very dilute acid dissolved a surprisingly large amount of aluminum oxid from the soils. There was practically no iron dissolved, not enough to impart a yellow tint to the aluminum hydroxid precipitate. The average amount of oxid from the four samples was 0.195 per cent. Aluminum may therefore exert an important influence in the neutralization of even very dilute acid, and this fact must be considered in the selection of an indicator designed to determine the free acidity of the final solution. A small amount of phosphoric acid was obtained in each case, but the difficulties attending a correct gravimetric determination of so small an amount in the presence of so much aluminum deterred us from attempting it. Attention should be called to the fact that the final acidity by methyl orange for the four soils was $\frac{n}{173}$, $\frac{n}{235}$, $\frac{n}{336}$, and $\frac{n}{415}$, respectively; and yet, in spite of the fact that the dilution was generally greater than recommended in the Moore method of digestion, small amounts of phosphoric acid were obtained in each case. As mentioned before, Moore obtained no phosphoric acid from these soils when phenolphthalein was used as an indicator in ascertaining the neutralizing power of the soil.

THE CHOICE OF INDICATORS.

The selection of an indicator for determining the final acidity of a dilute acid solution in which soil has been digested is in many cases a matter of considerable importance and demands more attention than has sometimes been given to it. Phenolphthalein, a weak acid indicator, has sometimes been employed; and again, methyl orange, one of the strongest acid indicators, with no apparent consideration of the great differences in results, which may, in certain cases, arise with the two indicators. The Association of Official Agricultural Chemists, in its "provisional method for the determination of the more active forms of the phosphoric acid in soils," recommends phenolphthalein as an indicator in ascertaining, by a preliminary

digestion, the amount of acid which is neutralized by the soil in order that a final acidity of $\frac{n}{5}$ may be secured. The original object of this preliminary digestion was probably to enable the method to be used with calcareous soils by increasing the acid by an amount which the lime of the soil was capable of neutralizing. Phenolphthalein, being sensitive to lime, was for this purpose an allowable indicator to employ. The situation changes, however, when a soil yielding much iron and alumina to dilute acid is analyzed; for these weaker bases certainly decrease the acidity in such a case, although phenolphthalein is incapable of measuring this decrease because it is not suitable for titrating such weak bases. The average amount of combined ferric and aluminic oxids dissolved from the soil of three of the limed plats by $\frac{n}{5}$ nitric acid was 1.456 per cent., while only one-tenth this amount, 0.146 per cent., of calcium oxid was dissolved, even though the plats had received, in previous years, two tons of air-slaked lime per acre. The average amount of silica was 0.265 per cent., and of phosphoric acid 0.015 per cent. Owing to the comparatively small amount of phosphoric acid its relative effect upon the two indicators mentioned may be left out of consideration. The silica and sesqui-oxids have, of course, different relative effects upon these indicators, but in view of the relatively large amount of the sesqui-oxids present in this case, to which methyl orange is sensitive and phenolphthalein is not, it is probable that the principal difference in the action of the two indicators may be attributed to the presence of the oxids of iron and aluminum in solution.

The extracts from digesting the soils of the various plats in $\frac{n}{25}$ nitric acid were titrated with $\frac{n}{14}$ ammonium hydroxid, using methyl orange and luteol as indicators. (As has been said, the latter indicator gave readings, with potash solution, similar to phenolphthalein.) The results show the remarkable differences which occur in such solutions with indicators of strong and weak acid properties. The final acidity as shown by the average of all of the samples being with luteol $\frac{n}{28}$, while with methyl orange it was only $\frac{n}{66}$. Again, four samples were digested in $\frac{n}{75}$ nitric acid, the average acidity after

digestion being $\frac{n}{95}$ with luteol and $\frac{n}{270}$ with methyl orange; these solutions contained on an average about 0.19 gram of aluminum oxid per liter.

In the original article by Moore, previously cited, in which hydrochloric acid of a final acidity of $\frac{n}{200}$ was recommended, methyl orange was prescribed as the indicator; whereas in the co-operative work with this solvent, upon the samples furnished from our phosphate plats, according to which no phosphoric acid was obtained, phenolphthalein was used as the indicator. It seems probable, from our results with nitric acid and the same soils, that, had methyl orange been used as the indicator in the preliminary determination for ascertaining the neutralizing effect of the soil upon the acid, an acid two or three times stronger would have been necessary in order to secure a final acidity of $\frac{n}{200}$. In which case it is possible that amounts of phosphoric acid bearing some relation to the productiveness of the plats might have been obtained, as was the case with the soils from various parts of the country examined earlier by the Bureau of Chemistry with $\frac{n}{200}$ hydrochloric acid, using at that time methyl orange as the indicator.

In order to gain further information regarding the relative sensitiveness of methyl orange and luteol to aluminum, a dilute solution of potassium-aluminum sulfate was titrated against a standard ammonium hydroxid solution. With methyl orange as an indicator the change of color began when a few tenths of a c.c. of the alkali had been added, while with luteol over 14 c.c. had to be added before the change of color occurred, which amount approached what would have been required by a quantity of sulfuric acid equal to that combined with the aluminum of the alum. In other words, luteol is not sensitive to aluminum, and, like phenolphthalein, is unsuitable for measuring the neutralizing effect of such weak bases upon the dilute acid used in soil digestion. It need scarcely be said that cochineal, which is so largely used in nitrogen determinations, is wholly unsuitable because of the pink color which iron and aluminum impart to it, resembling the change caused by an alkaline solution.

SUMMARY.

Owing to the marked influence of the reaction (acid or alkaline) of the soil upon the growth of certain plants, the effect of the different phosphatic materials upon this reaction must be considered in connection with a study of the assimilability of the phosphoric acid in those phosphates.

The assimilability of the phosphates themselves, and of the phosphorus of the soil, varies with the reaction of the soil.

The range in the percentage of phosphoric acid in oats, golden German millet, and Panicum crus-galli, fertilized with different phosphates, was not wide enough to serve as a measure of the assimilability of the phosphorus in different materials.

The results with flat turnips, however, indicate that this plant may serve a useful purpose in testing the relative assimilability of the phosphates.

The relative yields of turnip roots upon the limed phosphate plats, all of which had received the same amount of phosphoric acid, ranged between 1.7 and 27.0, depending upon the kind of phosphate, as compared with the limed check plat taken as 1.

The percentage of phosphoric acid in the dry matter of the turnip roots varied between 0.45 and 0.87; and in the tops, between 0.31 and 0.83.

The general tendency was for the percentage of phosphoric acid in the turnip crop to increase with the increase in the size of the crop brought about by the better kinds of phosphates.

It is possible that the percentage of phosphoric acid in the turnip may indicate the relative amounts of assimilable phosphoric acid in different soils, when certain conditions are well understood.

Half of the total amount of phosphorus in this soil is extracted with the humus. Much greater amounts of phosphorus were extracted from the soil with dilute ammonium hydroxid than by the same strengths of nitric acid.

Ammonium hydroxid of $\frac{n}{5}$, $\frac{n}{25}$, and $\frac{n}{100}$ strengths did not ex-

tract amounts of phosphorus in good accord with the assimilability of the phosphorus in the different plats. Fifth-normal and $\frac{n}{15}$ nitric acid also failed to uniformly point out the differences in the assimilability of the phosphorus as shown by the crop results.

The selection of an indicator for determining the neutralizing properties which a soil exerts upon an acid in which it is digested is of considerable importance, in view of the widely differing results secured by indicators of such different classes as methyl orange and phenolphthalein.

It is doubtful if any solvent will extract from all soils amounts of phosphorus bearing definite relations to those removed by even a given crop. This is especially truê when a large portion of the total amount of this element is in combination with organic matter and must depend, therefore, to a considerable extent, upon the microorganisms of the soil for its liberation.

ON THE CAUSES OF UNPRODUCTIVITY IN A RHODE ISLAND SOIL.

BY

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INTRODUCTION.

(BY H. J. WHEELER).

The following paper gives an account of some cooperative work between the Rhode Island Station and the Bureau of Soils of the U. S. Department of Agriculture. Mr. Breazeale was directed in his work by Professor Whitney, Chief of the Bureau of Soils, and by the Director of this Station.

The work was carried on primarily in order to study the soluble toxic substances in a highly unproductive soil and also in soils in good tilth and of high productiveness. The influence of the treatment of the extracts of such soils with non-nutritive solid materials and with certain soluble chemical substances has been studied by way of water cultures with wheat both in the normal and treated extract. It has been fully recognized that one can not necessarily apply the conclusions drawn from water cultures to ordinary field

practice, yet, by the study of water cultures of plants, valuable suggestions as to what occurs in the soil itself are often obtained. It is well known that the ordinary manurial substances contained in commercial fertilizers may sometimes injure soils, and they may also benefit them, even aside from their direct or indirect nutrient value upon the plants grown in them.

In earlier experiments at this Station a toxic effect upon plants was noticed after ammonium chlorid had been employed with acid phosphate and muriate of potash, but the toxic action disappeared when basic slag meal and potassium-magnesium carbonate were applied with the ammonium chlorid. A similar toxic effect was noticed also when ammonium sulfate was used with the same supplementary materials in the field and in pots, a condition which was overcome in the pots by the employment of either carbonate of lime or caustic magnesia. In the field lime only was employed, and then with full remedial effect. A single observation is also on record at this Station of a lack of toxic action when magnesium chlorid was added to a soil, while ammonium chlorid containing the same amount of chlorin was highly toxic. Possibly this latter action might not be repeated.

Many other illustrations of this double action of manurial substances could be cited from the field and pot experiments already conducted here. It is not surprising, therefore, that similar results should be obtained when working with water-extracts of soils.

The study of the influences of both soluble and solid substances upon these soil extracts is interesting and suggestive, and no one can predict its possible eventual bearing upon actual practice. To attempt to claim from the data obtained that because these manurial substances are beneficial to soil extracts in other ways than through their nutritive effects, where such a possibility of action exists, and that hence they do not play the role of plant nutrients in the soil when added, is not intended, nor is it to be inferred. Neither is it questioned but that the so-called chemical manures do in most instances, where they are applied to the "worn out" type of soils, exert a direct effect as nutrients upon the plants.

The action of the non-nutrient solids and of soluble bodies upon these extracts is not a source of surprise to those who understand the chemical and physical principles involved.

Owing to the lack of means, facilities, and assistants for undertaking such work at this time, the thanks of the Station are especially due to the Bureau of Soils for the aid rendered. It gives me great pleasure to acknowledge the valuable aid and suggestions made in connection with the work by Professor Whitney, Chief of the Bureau of Soils, also by Doctors Cameron and Livingston of the same Bureau. Thanks are likewise due Dr. B. L. Hartwell for assistance rendered to the authors in the course of the preparation of the manuscript of this article.

ON THE CAUSES OF UNPRODUCTIVITY IN A RHODE ISLAND SOIL.

Description of Soil.—The soil with which the present paper has to deal has been surveyed and mapped by F. E. Bonsteel and E. P. Carr. The following description is quoted from their report:*

"The soil of the Miami silt loam, to an average depth of 10 inches, is a brown silty loam containing a relatively small quantity of fine and very fine sand, which renders it mellow and friable. The surface compacts when wet, but does not bake on drying. The subsoil, to an average depth of 32 inches, is a uniform plastic yellow silt loam, becoming more sandy in the last few inches, and resting on a substratum of coarse sand and gravel below 32 inches. The whole type is free from stones and gravel except for a few glacial erratics and rounded bowlders scattered on the surface. Most of these have been picked off the fields and built into fences or crushed for road material.

"This type is found principally in the Kingston plain, where it presents a level surface, and near Peacedale, where it occurs as gently undulating hillocks and as a level table-land. Its range in elevation is slight, and the type as a whole is best described as level and unbroken.

"Underdrainage is generally good, from the coarse and porous nature of the materials underlying the subsoil at no great depth, but the surface is usually so level and the soil so compact that water stands on the surface after heavy rains and remains late in the spring after the melting of the snow. Areas sufficiently inclined to permit drainage, of course, do not suffer from standing water. The texture and structure of the soil and subsoil are such that they are capable of maintaining a sufficient moisture supply for the entire growing season; yet they are not so impervious as to impede the capillary movement of soil moisture, as do the heavy clays. The type

*Bonsteel, F. E., and Carr, E. P., Soil Survey of Rhode Island. Field Operations, Bureau of Soils, U. S. Dept. Agriculture, 1905.

therefore falls within the lighter class of desirable grass and grain producing soils, and is also adapted to a wide range of heavy truck and canning crops.

"The Miami silt loam is derived from reworked glacial material laid down as a sediment from quiet water under uniform conditions. These sediments form a superficial layer, rarely more than three feet in depth, over the coarser water-deposited materials of the plain. The predominance of silt in such a localized area in only one of the plains would point to the Miami stony loam, which occupies large surrounding areas, as the probable source of the materials. The pale color of the subsoil indicates the low state of oxidation of the iron salts, while the brown color and mellow texture of the soil indicate that it has been derived from the subsoil by direct weathering and the incorporation of organic remains."

The following table, taken from the same report, gives mechanical analyses of typical samples of this soil:

No.	LOCALITY.	DESCRIPTION.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
11,700	1 mile S. E. of Kingston	Brown silty loam, 0 to 10 inches.	2.1	6.7	4.2	9.5	12.5	53.8	11.2
11,698	½ mile E. of Slocum..........	Brown silty loam, 0 to 11 inches.	0.6	1.9	1.1	2.2	13.4	64.9	15.3
11,699	Subsoil of 11,698.	Yellow silty loam, 11 to 36 inches.	0.7	1.6	0.5	1.2	8.3	82.9	4.7
11,701	Subsoil of 11,700.	Yellow silty loam, 10 to 36 inches.	1.5	5.4	2.9	6.6	13.7	62.6	7.3

Methods.—The soil extract for these experiments was prepared by the method described in Bulletin No. 23 of the Bureau of Soils. One part of soil by weight was stirred three minutes with two parts of distilled water, then allowed to stand 20 minutes and filtered under pressure through a clean Pasteur-Chamberland filter. Since dis-

tilled water as it is ordinarily prepared in chemical laboratories has been found to be markedly toxic to wheat plants grown in water culture, and since this toxicity is in a very large measure corrected by filtering the water through carbon black,* all of the water used in these experiments was so treated. Distilled water was shaken thoroughly with well-washed carbon black obtained from the burning of petroleum, and the solid was then filtered out by means of filter papers. By this method any deleterious substances originally in the water were first removed before the soil extract was prepared, thus avoiding any question which might arise in regard to the properties of the water employed. All soil extracts and solutions were thoroughly aerated, by shaking, before they were used in the cultures.

The cultures were grown in wide-mouth bottles of black glass, capacity about 60 cc., the seedlings being fixed in small openings in the margins of the flat cork stoppers in the manner described in the bulletin above cited. The plants were so placed that the seed was just above the surface of the solution, while the roots were almost entirely submerged. The Russian variety of wheat known as "Chul" was used in all of these cultures. The seeds were germinated in moist sand and were transferred to the culture bottles when the sprouts had attained a length of from two to four centimeters, care being taken in preparing the experiments to use seedlings as uniform in size and vigor as possible. The experiment lasted about two weeks, and the media were replaced at intervals of three to four days by new ones freshly prepared. Weighings of the cultures were made at intervals of two or three days and the several losses in weight, being a measure of the amount of water transpired, were added together for the total transpiration. In these weighings three bottles were grouped together and considered as a culture unit. The cultures were grown in a glasshouse, and were given as large an amount of sunshine as was allowed by the weather. Under these conditions the effect of the increase in weight of the plants upon the determina-

* Breazeale, J. F. (1), Effect of solids upon the growth of wheat in water cultures, Bot. Gazette, 1905.

tions of the water transpired was negligible, and no account was taken of it. Loss of water by evaporation from the bottles was reduced to a quantity so small as to be also negligible.

It has been shown by Livingston* that under conditions similar to those of the present experiments the amount of water lost by transpiration is a fair measure of the growth of wheat plants during the first few weeks after germination, and this criterion was used in this work. At the end of the experiment the tops of the plants were removed just above the juncture of root and stem, and their green weights determined, the latter being taken as a second criterion of growth. It was found in these experiments that the results were not always the same by each of these criteria. A third criterion often of aid is the apparent general condition of the plant.

Experiments and Results.—In the beginning of this work a large sample of Miami silt loam was taken from that section of the Experiment Station farm known as the "artificially exhausted soil." This soil includes plats Nos. 74, 76, 78, 80, 82, and 84. It has been under continuous culture without grass for ten years, is in very poor chemical and physical condition, and does not represent the usual normal condition of this class of soils in Rhode Island. Indian corn will not attain a height of over five and one-half inches in this soil during the entire season. It was selected for these experiments on account of its low productivity. In an aqueous extract of this soil wheat seedlings made a very poor growth. Furthermore, certain peculiarities of the roots which characterize seedlings grown in the soil itself are also exhibited to a marked degree by the cultures in the soil extract. The roots are short and thickened and fail to branch normally. Evidently the immediate cause of the unproductiveness of this soil is transmitted to a considerable extent to its extract. This seems to be generally true whenever a soil and its extract are compared in this way. From this it appears that in the majority of cases the mechanical condition of the soil is not the only immediate

* Livingston, B. E., Relation of transpiration to growth in wheat, Bot. Gazette, 40, 178–195 (1905).

though possibly one of the primary causes of its failure to produce good crops, for a mechanical peculiarity of the soil can not be transmitted to an aqueous extract.

The properties of a solution may be effective in retarding the development of plants growing therein in one or both of two general ways: First, the physical properties of the solution, such as viscosity, osmotic pressure, etc., may retard growth or even inhibit it, and this without regard to the chemical nature of the dissolved substances to which the solution owes its properties. Second, the chemical nature of the solution may retard growth, either through the presence of bodies which are injurious to plants, or through the absence of necessary salts.

In attempting to determine the nature of the properties of the extract of the infertile Miami silt loam which makes it injurious to wheat plants, both of these possible modes of action need to be considered. Of the various physical properties of solutions the only one which is likely to be effective in this case is that of osmotic pressure. That the osmotic pressure of a solution may be too low to give the best growth of plants is very probable, although little has been done in the way of quantitative experimentation in this regard. Convincing qualitative evidence in favor of this idea has been presented recently.* It has been shown that the growth of wheat in a dilute nutrient solution is markedly increased by the addition of a soluble salt such as sodium chlorid, when sufficient amounts of this salt for all possible food requirements of the plants were already present in the solution. This increased growth was apparently due to the higher osmotic pressure of the solution acting directly or indirectly upon the plants.

It has long been known that the osmotic pressure of a solution might be too high for growth owing to the tendency of strong solutions to withhold water from the plant. Quantitative data on this subject are still markedly lacking in the case of higher plants. This

* Breazeale, J. F. (2), Effect of the concentration of the nutrient solution upon wheat cultures, Science, N. S. 22, 146–149 (1905).

whole subject is thoroughly discussed and the experimental evidence brought together up to the time of writing by Livingston.*

Several valuable studies have been made on lower forms. It is a well-known fact that in nutrient solutions which are too concentrated for normal growth, plants are in general either killed outright or show a dwarfing very similar to that produced by lack of water.

That certain soils contain soluble substances which are injurious to plant growth, apparently through their chemical nature, has long been known.† That extracts of soils are frequently toxic to plants has also been pointed out recently in Bulletin No. 23 of the Bureau of Soils of the U. S. Department of Agriculture, and this matter is treated more thoroughly for one particular soil in Bulletin No. 28 of the same Bureau.

Some of the possible causes of the injurious properties of the extract of the infertile Miami silt loam at Kingston, R. I., will now be considered.

In the first place, the effect of adding to the soil extract the three main plant-food constituents, potassium, phosphorus, and nitrogen, was tested. The salts used were potassium sulfate, disodium phosphate, and sodium nitrate. These were tried separately and in combination. Experiment I deals with these tests. It continued from April 22 to May 6, 1905, and comprised thirty-six plants for each of the different treatments. Transpiration data were taken for the last eight days of the period, and the green weights of the plant tops were determined at the end of the test. The data for this experiment are given in table I. The figures immediately following the names of the salts denote parts per million of the particular food constituents which were added, it being assumed on the ground of much similar experimentation that the small amounts of sulfate and sodium ions necessarily accompanying the food constituents would have at most a negligible effect upon the plant. Following the columns giving the

* Livingston, B. E., The rôle of diffusion and osmotic pressure in plants; Part II, Chap. IV, Chicago, 1903.

† See especially DeCandolle, A. P., Physiologie Végétale, Paris, 1832.

actual results are others which give the percentage gain brought about by the several treatments, these gains being calculated on the basis of the green weight and transpiration, respectively, of the cultures in untreated soil extract, considered as unity.

TABLE I.

DATA FOR EXPERIMENT I.

Treatment of extract of the infertile Miami silt loam with plant-food constituents.

TREATMENT OF EXTRACT.	TRANSPIRATION.		GREEN WEIGHT OF TOPS.	
	Grams.	Per cent. gain.	Grams.	Per cent. gain.
Untreated	68.0	......	2.85	......
K_2SO_4 (K 50 p.p.m.)	129.4	90	5.55	95
$NaNO_3$ (NO_3 50 p.p.m.)	102.9	51	4.90	72
Na_2HPO_4 (PO_4 50 p.p.m.)	148.5	119	6.75	37
K_2SO_4 and $NaNO_3$ (K and NO_3 each 50 p.p.m.)	185.2	172	5.50	93
K_2SO_4 and Na_2HPO_4 (K and PO_4 each 50 p.p.m.)	135.8	100	4.35	52
$NaNO_3$ and Na_2 HPO_4 (NO_3 and PO_4 each 50 p.p.m.)	172.8	154	5.20	82
K_2SO_4, $NaNO_3$ and Na_2HPO_4 (K,NO_3 and PO_4 each 50 p.p.m.)	242.2	256	4.25	49

From these results it appears that all of the treatments had a decidedly beneficial effect. This shows at once that the failure of the untreated extract to produce normal growth of wheat can not be considered as due to too high a concentration of dissolved substances, for the addition of these salts must have increased the concentration to a noticeable degree.

From the last paragraph it may be inferred that the concentration of this soil extract is too low to give normal growth of the culture plants. This is doubtless true, but the effect of the low concentration is apparently not the sole factor inhibiting growth. Experiment II, which was designed to throw light upon this point, is incon-

clusive. It was carried from May 5 to May 23, 1905, the transpiration being taken for the last eleven days. Thirty-six plants were used for each of the two treatments. The results are given in table II, which is arranged in the same manner as table I.

TABLE II.

Data for Experiment II.

Comparison of rain water with extract of the infertile Miami silt loam.

Treatment.	Transpiration.		Green Weight of Tops.	
	Grams.	Per cent. gain.	Grams.	Per cent. gain.
Soil extract prepared with filtered rain water.	67.7	....	3.1	....
Filtered rain water	73.5	9	3.1	0

While the transpiration of the plants grown in the rain water was somewhat higher than that of those grown in the soil extract, the difference is too small to draw any definite conclusions as to the relative gain of one over the other. It seems certain that the nutrient salts which were present in the soil extract were prevented in some way from exerting their due effect upon the plants.

Experiment III was another test of a similar nature, but in this case the soil extract was prepared with carbon-treated distilled water, and a portion was also diluted to twice its volume with the same water. This test was carried on with experiment I, the same number of seedlings being used for each treatment and the same culture in untreated extract being used as control. The result showed that the diluted extract produced an improvement in growth of seven per cent. by transpiration and 37 per cent. by green weight. These data support the idea mentioned above, yet further experimentation in the same line would be desirable.

Having shown that an important cause of the poor growth of wheat in this extract appears to lie in its chemical properties, there are two

questions which at once arise: First, can the facts be explained upon the supposition that the solution is deficient in nutrient salts? And, second, may the poor growth in the untreated extract be due, not wholly to a lack of beneficial and necessary chemical materials, but to the presence of some injurious or toxic substances?

An examination of the results of experiment I would seem to indicate that the first supposition is true, and that the extract is deficient in plant-food salts, a view which is supported by the small amount of salts in the extract, viz., 68 parts per million. It is possible that when one more of these salts is added growth is increased mainly because there is a better supply of nutrient material for the plant to draw upon. However, if the other supposition were also true, the addition of non-injurious soluble salts to the extract might so alter the conditions in the solution or in the plant, or in both together, that the injurious substances assumed in this supposition might become non-injurious. In other words, injurious substances may be present which prevent the plants from growing normally, and at the same time they may be suffering to some extent from a lack of nutrient salts.

Additional light upon these questions is obtained by comparing the growth of plants in a nutrient solution prepared with distilled water with the growth in another nutrient solution prepared with exactly the same salts in the same proportions, but with soil extract substituted for pure water. In this case the second solution must necessarily possess a somewhat greater content of soluble material than the former, since *some* substances must dissolve from the soil and be present in the extract. Therefore, if the nutrient solution prepared with soil extract exhibits a markedly poor growth as compared with the other solution, it must be concluded that the retardation of growth is due to the presence of injurious bodies.

Such a test of the properties of this soil extract was made as experiment IV. The nutrient solution used contained 82 parts per million of calcium nitrate and 88 parts per million of dipotassium phosphate. The experiment was carried on simultaneously with

experiment II, the same number of seedlings being used for each treatment. The data are given in table III. The percentage figures are calculated upon the basis of the normal nutrient solution, growth therein being considered as unity. It will be observed that they are negative in this case.

TABLE III.

DATA FOR EXPERIMENT IV.

Growth of wheat in nutrient solution prepared with pure water and with soil extract of the infertile Miami silt loam.

CULTURE MEDIUM.	TRANSPIRATION.		GREEN WEIGHT.	
	Grams.	Per cent. loss.	Grams.	Per cent loss.
Nutrient solution prepared with pure water..	120.5	....	4.2	....
Nutrient solution prepared with soil extract.	95.5	20.8	3.7	11.9

A marked deleterious effect was produced by the use of soil extract instead of pure water. There is, therefore, no logical alternative to the conclusion that the extract contains in solution substances which retard the growth of wheat in water culture. The nutrient solution was a dilute one, and the growth of the plants should have been improved by increasing its concentration. The optimum concentration for the growth of wheat* in a similar solution is about 300 parts per million of total salts, while the solutions employed contained only 170 parts per millon. An extract of this soil had a total salt content of about 68 parts per million, and thus the nutrient solution prepared from the extract should have contained in all not more than about 238 parts per million, a concentration which is seen to be far below the optimum for the growth of this plant. We must consider, then, that the injurious bodies of the soil exert their effect in retarding growth in spite of the slight increase in concentration produced by

* Breazeale, J. F. (2), loc. cit.

the presence of soluble salts in the extract. The possible presence of injurious substances is also suggested in the case of experiment II, and is shown as probable in experiment III already described; for the normal soil extract must have a slightly higher concentration than either distilled water or the diluted extract, and yet the plants remained in as good condition in water and made a slightly better growth in the diluted extract than in that which was undiluted.

Another method of attacking the problem as to whether the unproductiveness of this soil extract is partially or wholly due to the presence of deleterious substances is to determine whether a marked beneficial effect is produced by some treatment calculated to remove from the extract, or to destroy, any toxic substances that might be present, without at the same time adding any soluble bodies which might be of use to the plant as food material, or which might increase the concentration of the extract. In certain cases where toxic bodies have been shown to exist in soil extracts*, these bodies are removed or altered so as to become non-toxic by the introduction into the extract of practically insoluble or very slightly soluble solids in a finely divided condition. The solids which have so far been found to act in this way are precipitated ferric hydrate, carbon black, aluminum hydrate, quartz flour, and other substances which offer a large surface of contact with the extract. The first two of these and also recently formed limonite have been tested with this soil extract. Experiment V was the first in this connection. It was carried out at the same time and with the same number of plants as experiment I, and the same culture in untreated soil extract was used as control. Table IV presents the results. The amount of solid added to each 100 cc. of the extract is stated after the name of

* See Breazeale, J. F. (1), loc. cit. See also Bul. No. 28 of the Bureau of Soils, U. S. Dept. Agr., On the influence of the presence of solids on the action of toxic substances in solution; see True, R. H., and Oglevee, C. S., The effect of the presence of insoluble substances on the toxic actions of poisons, Bot. Gaz., 39, 1–21 (1905); a preliminary statement of these results appeared in Science N. S., 19, 421–424 (1904). Also see Dandeno, J. B., The relation of mass action and physical affinity to toxicity, etc., Am. Jour. Sci., 17, 437, 458 (1904.)

the solid. In this case and in those which are to follow only the percentage gains will be given, these being the only data which are of interest in these considerations.

TABLE IV.

DATA FOR EXPERIMENT V.

Effect of finely divided solids in extract of the infertile Miami silt loam.

Treatment of Extract.	Percentage Gain.	
	By transpiration.	By green weight.
Ferric hydrate, 0.5 gram	159	68
Carbon black, 0.1 gram	104	61

A comparison of these results with table I shows that the percentage gains here recorded are as great as many of those obtained where only one or two of the nutrient salts were employed. Experiment VI, which was carried on in the same series as experiment II, showed that recently formed limonite had an effect similar to, though less striking, than that of precipitated ferric hydrate. It caused a gain of 58 per cent. by transpiration and 16 per cent. by green weight.

The ferric hydrate used in experiment V was prepared from ferric nitrate and ammonium hydrate, and was thoroughly washed to free it as far as possible from adhering ammonia and ammonium nitrate. It was not allowed to dry, but was kept in the condition of a thin paste, and was added to the soil extract in this form and was then well shaken so as to secure its uniform distribution. The carbon black was prepared by the burning of petroleum and was thoroughly and repeatedly washed in boiling water and then allowed to dry. It was added to the soil extract in the dry form, and was thoroughly distributed by stirring. Fresh solid material was used whenever the extracts were renewed. It appears impossible that

the marked improvement which resulted from the addition of carbon black to the soil extract could have been due to any soluble materials which it carried into the solution, and the reason for its action appears to lie in its well-known absorptive power.

That the ferric hydrate used may have introduced into the solution small amounts of ammonia and of ammonium nitrate is possible. It has been found in the laboratories of the Bureau of Soils, however, that minute quantities of nitrates when added to a soil extract, or a dilute nutrient solution, produce but little appreciable beneficial effect; and the amount which was brought into solution in the extract by the ferric hydrate here used, after its thorough washing, must have been exceedingly small. Ammonia, prepared so as to remove any toxic metals possibly present, is still very toxic to wheat plants even in extremely dilute solutions, and no acceleration has been produced by its use in any concentration. Thus it is improbable that the beneficial effect of the ferric hydrate was due to either ammonium nitrate or to ammonia itself.

In order to reduce the last point to an absolute certainty, some ferric hydrate was prepared from ferric chlorid and sodium hydrate, thus avoiding altogether the possibility that ammonia or ammonium nitrate might be present in it. This was thoroughly washed and then divided into two portions, one of which was treated with ammonia and ammonium nitrate and then thoroughly washed again, while the other received no further treatment. Thus one of these portions of ferric hydrate should have been absolutely free from ammonia and ammonium nitrate, while the other may have contained a small amount of them in an absorbed state, so that washing with water failed to remove them. These two portions of ferric hydrate were subjected to tests in different portions of the same soil extract, to determine whether the solid which had been treated with ammonia and ammonium nitrate might be more or less effective than the other portion which probably contained small amounts of sodium hydrate and sodium chlorid.

This test will be termed experiment VII. The soil extract used

was from soil of plat No. 17 of the Rhode Island Agricultural Experiment Station, which has been in grass for seven consecutive years and has received annually applications of phosphates and potassium salts, but no nitrates nor other nitrogenous manures. The cultures were carried on from July 28 to August 12, 1905, having 28 plants for each treatment.

TABLE V.

DATA FOR EXPERIMENT VII.

Effect of ferric hydrate with and without ammonia, in extract of a Miami silt loam. (*Plat No.* 17.)

Treatment of Extract from Plat No. 17.	Percentage Gain.	
	By transpiration.	By green weight of tops.
Ammonia-free ferric hydrate	34.0	6.7
Ammonia-treated ferric hydrate	11.9	3.5

It is apparent at once that both lots of ferric hydrate produced some improvement in the growth of the plants, but that the effect of the ammonia-free material was more than double that of the other. This experiment shows that the beneficial effect of ferric hydrate as used in the other experiment was apparently not due to ammonia nor ammonium nitrate carried into the extract by the solid.

That a small amount of soluble iron is carried into the extract by ferric hydrate is probable, and it might be claimed that it would bring about the result which was observed; yet in other cultures to which iron was added in the metallic state, only a doubtful beneficial effect was produced, as in experiment VIII.

Ammonia-free ferric hydrate, ammonia-treated ferric hydrate, ferric hydrate prepared from ferric nitrate and ammonia, and metallic iron were included in this series. The extract used was made from the soil of the "infertile plats." The cultures were grown from

August 27 to September 9, 1905, 28 plants being used for each treatment. The results are given in table VI. Ferric hydrate, when indicated in the table, was shaken up with the soil extract and filtered out. The filtrate was then used for the cultures. The treatment with metallic iron consisted in adding about one-half of a gram of pure granular iron to each bottle and allowing this to remain during the growth of the plants.

TABLE VI.

DATA FOR EXPERIMENT VIII.

Effects of three preparations of ferric hydrate, when shaken with the soil extract and filtered out, and of metallic iron.

	Percentage Variation.	
	By transpiration.	By green weight of tops.
Amnonia-free ferric hydrate	182.9	0.0
Ammonia-treated ferric hydrate	67.2	3.1
Ferric hydrate made from nitrate and ammonia	139.9	4.7
Metallic iron (c. p.) added in small amount to extract	11.2	—2.0

This experiment agrees with experiment VII, as far as transpiration is concerned, in regard to the relative effects of the first two preparations of ferric hydrate. The variations in green weight are seen to be very slight in this case. The effect of metallic iron when present in the extract during the growth of the plants appears to be very small and doubtful in its direction, inasmuch as it was positive by transpiration and negative by green weight.

Since the ferric hydrate here used was not allowed to remain in contact with the soil extract during the growth of the plants, but was filtered out before the latter were placed in the extract, the increase in transpiration following this treatment must have been due to some action of the solid upon the soil extract rather than

upon the roots themselves, or to its action upon substances which may have been excreted from the roots or produced by the action of other organisms during the growth of the wheat plants.

In addition to what has been said above regarding the effect of ferric hydrate, it is well known that practically all soils contain enough iron for plant growth; and it has been found by experiment in the laboratories of the Bureau of Soils that a slight increase in the amount of soluble iron in several different soil extracts failed to produce any marked improvement in the plants.

That carbon black exerts its effects here mainly upon the soil extract rather than upon the roots of the plants or upon substances possibly excreted from these organs, was shown by experiment IX. In this experiment, extending from September 14 to 29, 1905, 24 plants were used in each treatment and the transpiration data were taken for eight days. The results above show that when the carbon black was left in the extract it produced an increase of 177.5 per cent. by transpiration and 45 per cent. by green weight, while when the solid was filtered out before the cultures were prepared the increase was 217.7 per cent. by transpiration and 53.3 per cent. by green weight.

From the results given above it may be concluded as practically certain that ferric hydrate exerts its effect through its absorptive power, and it is probable that carbon black, which also accelerates growth, is effective in the same manner. This indicates that the effect of these solids is probably not to add any soluble material to the extract, but to remove some material from solution. And since this removal of some substance or substances from the extract produces a marked increase in the growth of wheat, we are brought finally to the conclusion that the extract used in these cultures contained injurious bodies which are removed or rendered non-injurious through the absorbent action of finely divided solids. It will be recalled that Voelcker* found a soil extract to be toxic, and

* Jour. Roy. Agr. Soc. England, 64, 361 (1903).

Wheeler* *et al.* in 1895 suggested the possible presence of even non-acid toxic substances in soils.

It appears to be probable from evidence obtained in the laboratories of the Bureau of Soils† that there is considerable truth in the theory advanced by De Candolle in his Vegetable Physiology, and that wheat plants do excrete substances from their roots which are toxic to themselves. These substances seem to be more or less altered or removed from solution by the presence of either carbon black or ferric hydrate in the nutrient medium. From this fact it may be possible that some of the deleterious bodies which are met with in the culture tests in the extract of the infertile Miami silt loam were derived, at least in part, from the roots of the very plants used in the cultures. This is possible and to a certain extent probable even in those cases where the solid was not filtered out, owing to a lack of complete efficiency of the solid; but the conclusion that the soil extract at the outset contained deleterious substances and that these were partly removed or rendered much less toxic by the effect of the absorbing agents is rendered highly probable by the suggestions and facts brought out by experiments II, III, IV, VIII, and IX.

Another solid which, when used in the same way, is even more markedly beneficial than the solids just discussed, is calcium carbonate. It would hardly seem possible that the addition of this salt to the soil extract could produce a strikingly beneficial effect merely through the soluble calcium added. Calcium is one of the elements necessary to plant growth, but it is required by most plants in very small amounts, and wheat seedlings do not suffer appreciably from its absence in the nutrient medium during the first few weeks of their growth. In the case of extract of Takoma soil (see Bulletin No. 28, Bureau of Soils), it was found that calcium carbonate had a very marked beneficial effect just as it had here. In that case it was shown that this effect could not be related to calcium as a plant-food constituent, because calcium sulfate, although slightly beneficial,

* Eighth Ann. Rpt., R. I. Agr. Expt. Sta. (1895), p. 260; also Rpt. for 1900, p. 324.

† Breazeale, J. F. (1), loc. cit. Also Bulletin No. 28, Bureau of Soils, U. S. Dept. of Agr.

failed to show an effect parallel to that of the carbonate. The sulfate was tried in the present instance, but with this soil extract it had as marked an effect as the carbonate.* Experiment X included treatment of an extract of the infertile Miami silt loam with calcium carbonate by leaving the solid in contact with the solution during the growth of the plants and likewise by filtering it off before the plants were placed in the medium. It also included treatment with calcium sulfate, at the rate of 210 parts per million, and a triple treatment which consisted in shaking the extract with calcium carbonate, filtering out the excess, and then adding both ferric hydrate and carbon black, the latter solids remaining in the extract during the growth of the plants. This experiment was carried on simultaneously with experiment II, the same number of plants was employed and the same set of cultures in untreated extract was used as control. The results are given in table VII.

TABLE VII.

Data for Experiment X.

Effect of calcium carbonate upon extract of infertile Miami silt loam.

Treatment.	Percentage Gain.	
	By transpiration.	By green weight of tops.
Calcium carbonate in excess 0.5 per cent	139	23
Calcium carbonate, filtered out	106	16
Calcium sulfate, 210 p. p. m	134	39
Calcium carbonate, filtered out, ferric hydrate and carbon black, not filtered out	363	39

* In pot and field trials at the R. I. Station, in soil located but a few feet distant from the soil employed in this instance, the action of calcium sulfate was found to be much inferior to that of calcium carbonate when the actual amounts of calcium oxid were identical. See Sixth Ann. Rpt., R. I. Agr. Expt. Station (1893), p. 257; also Eighth Ann. Rpt., R. I. Agr. Expt. Station (1895), p. 269. This shows that one can not necessarily conclude from water cultures what will result in the soil itself.—H. J. Wheeler.

It appears that when the carbonate is shaken with the extract and then filtered out it has a somewhat less marked effect than when it is left in contact, and that calcium sulfate has about the same effect as the carbonate when the latter is not filtered out. It also appears that after treating with calcium carbonate and filtering, the extract was further improved by the addition of ferric hydrate and carbon black. A test of the effect of ferric hydrate, carbon black, and calcium carbonate, all left in contact with the extract, constituted experiment XI, which was carried on in the same series as experiment I. The result showed a gain of 226 per cent. by transpiration and 81 per cent. by green weight. The effect of the carbonate may be partly due to its absorbent power as a finely divided solid, but the effect of the sulfate can not be explained in this manner, since the salt was added in solution. Therefore, since the latter salt is just as effective as the carbonate, it appears probable that soluble calcium, either as sulfate or carbonate is an active agent in correcting the toxicity of the soil extract. It is possible that the toxic substances of the extract are altered by the presence of these calcium salts in solution so as to become non-toxic.

Although, as has been noted above, it is improbable that the effect of the calcium salts is wholly due to their nutrient value, yet this point has not yet been established on an experimental basis. There is at least one other substance, however, which has a beneficial effect and which can not possibly be considered as a plant-food constituent. This is pyrogallol, which contains nothing but carbon, hydrogen and oxygen, and can therefore possess no nutrient value. As in the case of the extracts of Takoma soil (Bul. No. 28, Bureau of Soils, U. S. Dept. Agr.), small amounts of this phenol were found to have a marked beneficial effect upon the present extract. The test of this, experiment XII, was included in the same series with experiment II and comprised the same number of plants. The treatments and results are shown in table VIII. The phenol was added in solution so as to give several different concentrations in the extract. It was found in the case of the Takoma soil that large amounts of pyrogallol

had an injurious effect, but that the injury was avoided without at the same time destroying the beneficial effect of the phenol by neutralizing it with trimethylamine. In the present experiment the phenol was added at the rate of 40 parts per million, and then enough trimethylamine was added to neutralize the acidity of the treated extract.

TABLE VIII.

DATA FOR EXPERIMENT XII.

Effect of pyrogallol upon extract of the infertile Miami silt loam.

TREATMENT OF EXTRACT.	PER CENT. VARIATION.	
	By transpiration.	By green weight of tops.
Pyrogallol 1 p. p. m.	10	0
Pyrogallol 5 p. p. m.	24	—6
Pyrogallol 10 p. p. m.	53	6
Pyrogallol 25 p. p. m.	93	3
Pyrogallol 40 p. p. m., neutralized	83	6

The figures show that pyrogallol was undoubtedly beneficial. The effect was quite marked, as shown by transpiration figures, but practically no differences were shown by the green weight of tops. In general appearance the plants showed the effect as markedly as do the transpiration figures.

Since the results here presented can not be explained on the ground that a nutrient substance had been added, and since the amount of pyrogallol added was not sufficient to alter the physical concentration of the soil extract to any appreciable degree, the logical conclusion seems to be that the toxic substances of the extract are so acted upon by the pyrogallol as to become less injurious. In this regard this soil is similar to Takoma lawn soil, though the effect of the phenol is less pronounced.

In connection with experiment I, attention was called to the fact that the transpiration and weight of plants grown in this soil extract were markedly increased by the addition of the nutrient salts. But since similar results to a greater or less extent can be obtained without the addition of nutrient material, as in experiments with pyrogallol, ferric hydrate, and carbon black,* it seems possible that in some cases the addition of these nutrient substances may have an effect aside from merely increasing the nutrient value of the solution. This view is strongly supported by the observation, made in experiment X, that calcium sulfate when added to the extract in the proportion of 210 parts per million produced such a marked gain in transpiration and green weight, and by a further observation that sodium chlorid in the proportion of 230 parts per million acted in the same way. The last observation was made in experiment XIII, which was included in the series with experiment II, having the same number of plants and the same control. Sodium chlorid, added to the soil extract in the proportion of 230 parts per million, produced a gain of 34 per cent. by transpiration and 13 per cent. by green weight. It will be noticed that this treatment was not as effective as the addition of the usual nutrient salts nor as the addition of calcium sulfate. It is possible that sodium chlorid failed to show as great an increase as the other salts because of the toxic and therefore retarding effect of the chlorin ion. The toxic action of certain chlorids in pot experiments in the absence of basic compounds has been shown by the Rhode Island Agricultural Experiment Station, but in the presence of basic substances no apparent toxic action was observed.

The question regarding the effect of concentration of the nutrient solution on the growth of plants is discussed in a paper already cited,† and the suggestion is there made that the effect of higher concentration in improving the growth of the plants is probably due to some alteration thus produced in the relation between the plant and the toxic substance excreted by its roots. It is stated that:

* Whether the calcium sulfate and calcium carbonate, which were highly beneficial, are to be regarded as nutrients or otherwise in this connection is still an open question.

† Breazeale, J. F., loc. cit. (2).

"The effect of increase in concentration may be explained by one or more of the three following hypotheses: The higher concentration may make the plant more resistant to the poisons; it may actually prevent the excretion of such poisons from the roots; or with higher concentration of salts the poisons themselves may be altered so as to lose their toxic properties."

In the case of these soil extract experiments where the solution is changed frequently, a beneficial effect due to an increase in concentration by the addition of salts is hardly possible, excepting through the first and last of the three means suggested. The higher concentration may cause the plant to become more resistant to the toxic bodies of the extract, or these bodies themselves may be altered so as to become non-toxic. It is at present impossible to decide finally between these possibilities.

Two experiments were carried out in order to make possible a comparative study of the effects produced in the extract of the infertile soil by carbon black, ferric hydrate, the manurial salts, and sodium chlorid. Experiment XIV dealt with ferric hydrate and comprised 24 plants. It continued from September 8 to September 23, 1905, the transpiration being for the last nine days of the period. The treatments and results are given in table IX. In Nos. 3 and 4 the solid and soluble salts were both present throughout the growth of the plants. The total salt content in No. 1 was 254 p. p. m.; therefore the total percentage of salts was the same in all three treatments in which they were employed. This was also true of all the following experiments.

TABLE IX.

DATA FOR EXPERIMENT XIV.

Relative effects of ferric hydrate, manurial salts, and sodium chlorid in extract of the infertile Miami silt loam.

Number.	Treatment of Extract.	Percentage Gain. By transpiration.	Percentage Gain. By green weight.
1	NO_3, K, PO_4, each 50 p.p.m., in $NaNO_3$, K_2SO_4 and Na_2HPO_4	317.6	137.5
2	Ferric hydrate, not filtered out	247.6	114.0
3	Treatment of (2) and (1)	323.4	129.1
4	Treatment of (2) + NaCl 254 p.p.m	230.6	50.2

It is seen from the table that all of the treatments had a very marked beneficial effect. The effect of the manurial salts, with or without the solid, was considerably greater than that of the solid (ferric hydrate), while the effect of sodium chlorid with the solid was less than that of either the manurial salts or the ferric hydrate when used alone. It thus seems clear that the effect of the solid was not diminished by the presence of manurial salts, but that this effect was diminished by the presence of sodium chlorid. This strengthens still further the suggestion made above, that the latter salt had an injurious effect in the extract.

Experiment XV dealt with carbon black, and comprised 24 plants for each treatment. It extended from September 14 to September 29, 1905, the transpiration data being taken during the last eight days. The treatments and results are shown in table X.

TABLE X.

DATA FOR EXPERIMENT XV.

Relative effects of carbon black, manurial salts, and sodium chlorid in extract of the infertile Miami silt loam.

Number.	Treatment of Extract.	Percentage Gain.	
		By transpiration.	By green weight.
1	NO_3, K and PO_4, each 50p. p. m., in $NaNO_3$, K_2SO_4 and Na_2HPO_4	458.3	194.4
2	Carbon black, filtered out	217.7	53.3
3	Treatment of (2) and (1)	563.4	191.7
4	Treatment of (2) + NaCl 254 p. p. m.	164.8	61.5
5	Carbon black, not filtered out	177.5	45.0
6	Treatment of (5) and (1)	537.9	240.7
7	Treatment of (5) + NaCl 254 p. p. m.	215.2	74.2

This experiment agreed with the last in that both manurial salts and carbon black had a marked beneficial effect, and also in that the beneficial effect of the manurial salts was greater than that of the solid, this being true whether the latter was filtered out or not. When either method of carbon treatment was used in connection with the manurial salts the combined effect was greater than that of either when used alone. This single experiment indicated that the additional carbon treatment somewhat improved the effect produced by the manurial salts alone, which was not observed in the preceding experiment with ferric hydrate. When the solid was filtered out, the addition of sodium chlorid to the treated extract produced no marked additional increase in growth, although the two criteria, transpiration and green weight, are not in accord on this point. When the carbon black was not filtered out, the addition of the last-named salts produced a definite improvement. It appears possible, therefore, that

a part of the effect produced by the manurial salts may have been due to an increase in the concentration of the soil extract, that sodium chlorid had a smaller effect in the same way, and that carbon black had an effect in some manner different from and practically independent of the other two treatments.

To compare the results of the last two experiments upon the infertile soil with the effects produced upon good soils, the three following experiments were performed: Experiments XVI and XVII were similar to experiment XV, and dealt with ferric hydrate and carbon black, respectively, in an extract of soil from plat 29 of the Rhode Island Agricultural Experiment Station. This plat has been treated annually with but few exceptions for a period of twelve years with approximately 800 pounds of dissolved bone-black; 300 pounds muriate of potash; 465 pounds sodium nitrate; and, for a lesser period of time, 400 pounds sulfate of magnesia per acre. Three applications of lime were made during the entire period. The plat was in legumes at the time the sample was taken, and the growth of certain varieties of these plants showed the soil to be in good condition, while other varieties showed the reverse to be true. At all events this soil stands in marked contrast to the infertile soil with which the preceding experiments (excepting experiment VII) have had to deal, for, as is stated on page 292, that soil was in an exceedingly poor condition, as shown by the last crop grown upon it.

Experiment XVI comprised 24 plants for each treatment. It was continued from September 24 to October 9, 1905, the transpiration measurements being made during the last ten days. The results are presented in table XI.

TABLE XI.

DATA FOR EXPERIMENT XVI.

Relative effects of ferric hydrate, manurial salts, and sodium chlorid in extracts of soil from Plat 29, Rhode Island Agricultural Experiment Station.

Number.	Treatment of Extract.	Percentage Variation.	
		By transpiration.	By green weight.
1	NO_3, K and PO_4, 50 p. p. m. each, in $NaNO_3$, K_2SO_4, Na_2HPO_4	172.7	95.7
2	Ferric hydrate, filtered out	91.1	2.4
3	Treatment of (2) and (1)	214.7	112.0
4	Treatment of (2) + NaCl 254 p. p. m	96.5	13.7
5	Ferric hydrate, not filtered out	85.3	—2.8
6	Treatment of (5) and (1)	207.4	103.8
7	Treatment of (5) + NaCl 254 p. p. m	135.5	16.6

Experiment XVII comprised 24 plants for each treatment, and was continued from October 2 to October 16, 1905, transpiration being determined for the last five days. The results are given in table XII.

TABLE XII.

DATA FOR EXPERIMENT XVII.

Relative effects of carbon black, manurial salts, and sodium chlorid in extract of soil from Plat 29, Rhode Island Agricultural Experiment Station.

Number.	TREATMENT OF EXTRACT.	PERCENTAGE VARIATION. By transpiration.	PERCENTAGE VARIATION. By green weight.
1	NO_3, K and PO_4, 50 p. p. m. each, in $NaNO_3$, K_2SO_4 and Na_2HPO_4	117.9	88.1
2	Carbon black, filtered out	17.2	—10.3
3	Treatment of (2) and (1)	110.0	77.8
4	Treatment of (2) + NaCl 254 p. p. m.	55.8	24.2
5	Carbon black, not filtered out	20.8	—31.4
6	Treatment of (5) and (1)	76.6	73.1
7	Treatment of (5) + NaCl 254 p. p. m.	20.2	5.5

In these experiments the effect of the manurial salts when used alone was much less than in the case of the poor soil, as should be expected from general field experience, for this soil has a comparatively high productive power, and is probably not capable of very marked improvement for most varieties of plants. The effects of ferric hydrate and carbon black were far less beneficial than in the case of the infertile soil. They were both helpful in this instance, as concerns the transpiration, but these effects become practically negligible, in view of the accompanying losses in green weight, in three of the four instances. The effect of the manurial treatment was benefited to some extent by treatment with ferric hydrate, yet these differences were too small to be strongly conclusive. Its effect was diminished by a similar additional treatment with carbon black. When the sodium chlorid treatment followed that with ferric hydrate where the latter was removed by filtering, the com-

bined effect was a little greater than with the solid alone, and this condition was much more decided when the chlorid was added to the extract with the ferric hydrate remaining in contact. When the extract was shaken with carbon black and the solid filtered out, and then sodium chlorid added, the chlorid seemed to be beneficial; but its effect was slightly injurious, as indicated by the transpiration, when carbon black was allowed to remain in the extract. It should be borne in mind, however, that many of the differences were too small to have any particular significance.

Experiment XVIII was similar to experiments XVI and XVII, but was carried out with an extract of soil from plat 11 of the Rhode Island Agricultural Experiment Station. This is one of the plats in rotation "C." The rotation used is winter rye, clover, and potatoes, each one year. During the season of 1905 this plat was in potatoes. The manurial treatment in the earlier years of the rotation is described in Bulletin No. 74 (1900). In the later years only minor changes have been made. The soil is in good agricultural condition, as shown by the recent crops taken from it. The present experiment comprised 24 plants for each treatment, and continued from October 2 to October 17, 1905, transpiration being determined for the last five days. The results are given in table XIII.

TABLE XIII.

DATA FOR EXPERIMENT XVIII.

Relative effects of carbon black, ferric hydrate, manurial salts, and sodium chlorid in extract of soil from Plat 11, Rhode Island Agricultural Experiment Station.

Number.	TREATMENT OF EXTRACT.	PERCENTAGE GAIN.	
		By transpiration.	By green weight.
1	NO_3, K and PO_4, 50 p.p.m. each, in $NaNO_3$, K_2SO_4 and Na_2HPO_4	139.7	99.1
2	Carbon black, filtered out	45.9	9.2
3	Treatment of (2) and (1)	167.0	113.0
4	Treatment of (2) + NaCl, 254 p.p.m.	63.9	9.7
5	Carbon black, not filtered out	106.1	0
6	Treatment of (5) and (1)	150.1	80.5
7	Treatment of (5) + NaCl, 254 p.p.m	64.9	19.4
8	Ferric hydrate, filtered out	51.5	8.4
9	Treatment of (8) and (1)	177.3	115.2
10	Treatment of (8) + NaCl, 254 p.p.m.	60.8	15.1
11	Ferric hydrate, not filtered out	42.8	1.7
12	Treatment of (11) and (1)	153.6	128.7
13	Treatment of (11) + NaCl, 254 p.p.m.	47.4	23.2

This soil resembles that of plat 29, giving only comparatively slight increases with manurial salts, with ferric hydrate or with carbon black, as compared with the first one employed. As was noted in the case of the soil of plat 29, this failure is probably related to the fact that this soil already has a relatively high productive power and can not be improved by any treatment. As before, the manurial salts gave a much greater increase in green weight and transpiration than the two solids. The combination of ferric hydrate or of carbon black with the manurial salts, excepting the green weight

in No. 6, gave a greater increase than was produced by either treatment alone. The addition of sodium chlorid to the extract which had already been treated with ferric hydrate or carbon black produced a very slight increase above what would have been obtained without the chlorid; indeed a negative effect on the transpiration was produced by the chlorid in No. 7, which was treated with carbon black not filtered out.

From the results obtained in experiments XIV to XVIII, the most obvious, and likewise the most important, conclusion to be drawn is that in the case of the extracts of the infertile soil the manurial treatment and the treatments with ferric hydrate and carbon black were much more beneficial than the same treatments in the case of the good soils of plats 29 and 11. These experiments also show clearly that the effect of the manurial salts was much greater on the extracts of both poor and good soils than the effects produced by treatment of the extracts with the absorbing solids, ferric hydrate and carbon black.

The beneficial effects derived from the solids in experiments XIV to XVIII were always increased by the further treatment of the extract with manurial salts. The effect of the manurial treatment is shown to have been increased somewhat by ferric hydrate, whether the solid was filtered out or not, even in the case of the extracts of the two good soils. In the case of the poor soil the only test bearing upon this point is that of experiment XIV, in which the solid was left in the extract. In that test the criterion of transpiration showed the effect of the manurial salts to be increased by the solid, while the criterion of green weights showed the opposite. Therefore, the test is inconclusive. In the case of the poor soil the effect of the manurial salts was increased by further treatment of the extract with carbon black when the solid was not filtered out. When this solid was filtered out the evidence from the two criteria, transpiration and green weight, is discordant. A consideration of the large positive effect exhibited by the former criterion and of the small negative effect exhibited by the latter can merely be said to be

suggestive in the same line. With the extract of the good soil from plat 29 the carbon treatment diminished the effect of the manurial salts. In the extract of soil from plat 11 the effect of the manurial salts was increased by carbon black when filtered off, but when the solid was left in the extract there was again a discrepancy between the two criteria, transpiration showing an increase and green weight a decrease.

Summarizing the points brought out in the last paragraph: The injurious effects of the solids were overcome in all cases and the beneficial effects of the solids were increased in other instances by the addition of manurial salts. The effect produced by the manurial salts was slightly improved by ferric hydrate in the case of the two good soils, conclusive data being lacking for the poor soil. The effect of the manurial salts was probably improved by carbon black as shown by transpiration and green weight, except for a lesser green weight in one of the two trials, in the case of the poor soil. This effect was diminished by carbon black in the case of the soil from plat 29, and was by no means shown to be positively increased in that of the soil from plat 11.

It has been pointed out in earlier paragraphs that the soil extracts were often apparently benefited (1) by increasing their physical concentration, though in some instances injury resulted; (2) by increasing the amount of manurial salts; and (3) by removing or altering the toxic bodies which appear to be present in them. The beneficial effect of carbon black and ferric hydrate appears to have been due probably to the removal or alteration of toxic bodies. The beneficial effect of the manurial salts may be brought about in all three of the ways mentioned, though no positive evidence of the latter action has been brought forward. Addition of these salts assuredly increases the concentration (and that without the addition of a toxic body like sodium chlorid), increases the supply of mineral nutrient materials, and may possibly bring about chemical changes in the toxic bodies of the extract, resulting in their becoming less toxic. To separate the well-established nutrient value of a salt

from this suggested sanitary value, which appears to exist, and to show positively the actual existence and extent of the latter, must require very extensive and painstaking work. The present contribution can not be said to have done more than to have barely touched upon this problem.

The fact that in some cases treatment of the soil extract with an absorbing solid followed by the addition of the manurial salts gave a greater increase in the growth of the plants than was obtained with the soluble salts alone shows quite clearly that the functions of these two classes of substances are different, or that insufficient amounts of each were used. As has been said above, the manurial salts may have been effective in increasing the concentration of the extract and in furnishing a larger supply of nutrient materials. The absorbing solids can not be effective in this way, and their effect is probably to be attributed to a removal or alteration of the toxic bodies of the extract.

Regarding the effect of sodium chlorid in these experiments, when this salt was added to the soil extract which had already been treated with a solid with or without its subsequent removal, the result in the case of the poor soil was in one instance to decrease both transpiration and green weight, in another to lower the transpiration and to raise the green weight, and in another to raise both. Excepting the transpiration in two instances in the case of the better soils (plats 11 and 29), the results pointed to slight or decided benefit from the sodium chlorid.

As has been suggested previously, the effect of sodium chlorid is probably brought about by two antagonistic sets of factors, the beneficial effect of increase in physical concentration and of possible action upon toxic bodies, and the injurious effect of the increase in the concentration of the chlorin ions. If this be true it is not difficult to explain the apparent difference between the effect of this salt in solid-treated extracts of the poor soil and of the good soils. In the extract of the poor soil more toxic principles are still acting which retard the growth of plants. In the extract of the good soils the

injurious factors are not nearly so active, and after treatment with the solids they are perhaps practically removed. Thus in the latter extract, owing to the presence of a lesser amount of toxic substances, the plants might not show injury upon the addition of chlorids, especially in view of the previous liming of both of these soils, while the beneficial tendency of the increase in physical concentration which accompanies the addition of the chlorid should be equally potent in both extracts. The problem regarding the effect of sodium chlorid in soil extract or nutrient solutions is still further complicated by the possibility that some part of the beneficial effect often derived from its use is due to direct benefit to the plant itself, as suggested by certain unpublished experiments by the authors, and also by the bare possibility that it has a favorable chemical effect upon certain toxic bodies of the soil itself, in a manner similar to that suggested above as possible for certain manurial salts. Thus the problem here is seen to be an exceedingly complex one which will require a great deal of careful experimentation before a complete solution of it may be hoped for.

SUMMARY.

In the present paper it is shown that the unproductiveness of the infertile Miami silt loam from the farm of the Rhode Island Agricultural Experiment Station, at Kingston, R. I., is in some measure transmitted to the aqueous extract of this soil. The physiological properties of this extract have been investigated in several particulars.

There are at least four different ways in which it is possible for a soil extract to retard growth: First, it may have too high a physical concentration; second, it may have too low a concentration; third, it may not contain a sufficient supply of plant-food constituents; and fourth, it may contain substances which are injurious to plants. The first of these possibilities concerning this particular soil extract is at once ruled out of consideration, because the addition of salts to this extract increased plant growth therein. The second possi-

bility might in a measure be considered as ruled out by the fact that the diluted extract gave at least as good growth as was obtained in the normal extract; yet it is quite possible that the benefit arising from a dilution of toxic substances present in the extract might be sufficient to fully offset the tendency to lessen growth by diluting the nutrient materials. Treatment of the extract with finely divided carbon black and ferric hydrate must seemingly be effective through the absorbing power of these solids, and the beneficial effect of this treatment must probably be regarded as due to the removal of some substances from the extract. This seems to indicate that the extract contained injurious bodies which were removed from or altered in the soil extract so as to become non-injurious, or partially so, by the action of the solids above named. Some evidence in the same direction is derived from the fact that treatment of the extract with pyrogallol produced a gain in transpiration in all cases and in green weight in three of the five instances. This phenol can not be considered as a nutrient material, so that the conclusion is suggested that certain toxic substances present in the extract are acted on chemically by the pyrogallol and brought into a less injurious form. It is suggested that the beneficial action of calcium carbonate and calcium sulfate in these experiments may be in part of a similar nature.

The soil extracts were unquestionably improved for the growth of wheat plants by the addition of considerable amounts of sodium nitrate, potassium sulfate, sodium acid phosphate, and in certain cases by sodium chlorid. The beneficial effects brought about by these salts may, *a priori*, be due to one or more of four possible modes of action: (1) They increase the physical concentration of the extract, and this may make the plants less susceptible to the injurious action of the toxic bodies. (2) They may act chemically upon the plants, and by furnishing them with nutrient or stimulating materials may thus enable them to better withstand the action of the toxins. (3) Some or all of the salts may act chemically upon the toxic substances themselves, in the manner suggested for pyrogallol and

the calcium salts. (4) They unquestionably do act as plant nutrients, excepting possibly sodium chlorid under certain conditions. The evidence seems to point to the idea that one or more of the first three of these modes of action may sometimes be important, aside from or in conjunction with the fourth; but the problem of analyzing the general effect into its particular components and relating each component to its cause is one which lies far beyond the reach of the present researches. The question as to just how the salts acted in all particulars must be left an open one for the present.

A comparison of the effects produced by the various treatments of the extract of the infertile soil with those produced by the same treatments upon extracts of two soils of the same farm which were in good condition for the growth of crops shows that none of the treatments produced nearly as good effects upon the extract of the good soil as upon that of the poor soil; yet treatment with carbon black and ferric hydrate in a few cases seemed to produce a small beneficial effect upon the extracts of the good soils, and these bodies were probably effective through the removal of injurious substances from the extract. Therefore it may be supposed that the toxic bodies which apparently exist in relatively large amounts in the extracts of the infertile soil may be present also to a slight extent in that of the good ones.

The soluble toxic bodies of the infertile soil seem in some respects to be similar in their effect to those which have been shown to exist in the Takoma soil, as described in Bulletin No. 28 of the Bureau of Soils. The extracts differ mainly in the degree and character of the effect which nutrient salts, calcium sulfate, and pyrogallol exert upon plants growing therein.

DIVISION OF ANIMAL HUSBANDRY.

In the absence of a report from this Division, readers are referred to the report of the Director, pages 179 to 183, for a brief statement of what has been done during the year.

REPORT OF METEOROLOGIST.

NATHANIEL HELME.

Some changes have taken place in this division during the past year. In view of the fact that a station of the U. S. Weather Bureau with an official forecaster in charge was located in Providence in October, 1904, the special predictions which for a little more than fourteen years have been sent from here to the Evening Bulletin, were discontinued at that time, and at the end of the year the monthly summaries which had been published in that paper were discontinued for the same reason. In March, 1905, a letter from the Weather Bureau Station in Boston stated that, owing to the limited appropriation for telegraph service, the weather forecasts which had been sent from there daily, and had been displayed here by means of flag signals from the belfry of Library Hall in Kingston village, would have to be discontinued, but if the public wished it, it might be resumed after July 1st.

Summary for 1904–1905.

Highest temperature	87°	July 19, 1904.
Lowest temperature	—4°	February 4, 1905.
Range for the year	91°	
Highest monthly mean	68.3°	July, 1904.
Lowest monthly mean	21°	February, 1905.
Highest daily mean	75°	July 19 and 20, 1904.
Lowest daily mean	7.5°	February 4, 1905.
Mean temperature of the year	45.3°	

Precipitation (rain and melted snow).

Greatest in any 24 consecutive hours	2.48 inches, August 10, 1904.
Greatest total for one month	7.63 inches, August, 1904.
Smallest total for one month	1.69 inches, May, 1905.
Total for the year	41.64 inches.
Total snowfall (unmelted)	51.00 inches.

Prevailing Winds.

Southwest: July, August, September, 1904; May, June, 1905; West: October, November, December, 1904; January, February, March, April, 1905.

Weather.

Number of clear days in the year 151
Partly cloudy days 122
Cloudy days 92
Days with .01 inch or more of precipitation 99

Summary by Months for 1904–1905.

MONTHS.	Highest temperature.	Lowest temperature.	Mean temperature.	Precipitation (rain and melted snow), inches.	Snowfall (unmelted).	Clear days.	Partly cloudy days.	Cloudy days.	Days with .01 inch or more of precipitation.	Prevailing wind direction.
1904.										
July	87°	48°	68.3°	2.47	......	10	13	8	9	S.W.
August	83°	45°	66.3°	7.63	......	12	10	9	8	S.W.
September	82°	29°	60.6°	1.97	......	12	12	6	10	S.W.
October	78°	20°	48.2°	2.30	......	16	8	7	4	W.
November	57°	7°	35.4°	3.15	1¾	15	12	3	5	W.
December	50°	4°	23.1°	4.97	28	7	15	9	11	W.
1905.										
January	49°	—1°	28.9°	4.37	13	14	10	7	11	W.
February	45°	—4°	21.0°	2.18	8½	15	5	8	5	W.
March	68°	8°	34.7°	2.86	......	13	9	9	10	W.
April	70°	23°	44.5°	2.83	......	11	12	7	8	W.
May	80°	30°	55.0°	1.69	......	14	8	9	9	S.W.
June	85°	38°	62.8°	5.22	......	12	8	10	9	S.W.
Total	......	......	......	41.64	51¼	151	122	92	99	......
Mean	69.5°	20.6°	45.3°	......	......	......	......	......	......	......

The principal characteristics of the weather for each month were as follows:

The July mean temperature was 1° below the average for the month. There were no extremely high temperatures, but the large percentage of humidity made the weather uncomfortable at times. The rainfall was one inch less than the mean for the month for 16 years.

The mean temperature of August was nearly 2° below the average for the month for 16 years. During the first two decades of the month the rainfalls were frequent and heavy, making the total for the month three and one-half inches above the average and the largest for August on our record.

The September mean temperature was below, and the rainfall one-half, the average for the month for 17 years. The minimum temperatnre of 29° was the lowest for September on our record.

October was a month of fine autumnal weather, with an abundance of sunshine. The mean temperature was below the average, and the lowest for the month since 1895. The rainfall was less than one-half the average for 17 years.

The November mean temperature was below the average, and it was the coldest November on our record. There was a flurry of snow on the 6th, and the first snow of sufficient depth to measure fell on the 27th. The precipitation was below the average.

The mean temperature of December was 7° below the average, making it the coldest on our record. This was owing to the low maxima rather than to any extremely low temperatures, as at no time did it register zero or below as has been the case in December in previous years. The ground was covered with snow for the greater part of the month, and there were several days of good sleighing.

The January precipitation and temperature were each below the average for the month, and at the end of the month there was no snow on the ground.

It was the coldest February on our record. There was snow on the ground throughout the month, and the total precipitation was less than one-half the average. The mean temperature of the three winter months of 1904–1905 was 22.7° and for the same time in 1903–1904 it was 22.6°, making but a slight difference between the two.

March was notable for absence of the high winds which generally prevail in that month. The precipitation was less than one-half the average, while the mean temperature was about the normal.

The April mean temperature was but slightly below the average. At the close of the month vegetation was not very far advanced, it having been hindered by the cold nights and not very warm days.

May was quite a dry month, the rainfall being less than one-half the average for the month. There was a killing frost on the 2nd, and light frost on low land on the 21st and 22nd. The temperature was about the normal for the month.

The June temperature was below, and the rainfall above, the average for the month. There was frost on low land on the morning of the 9th.

The following tables give the temperature, rainfall, wind direction and character of the day for each day of the year, and a general summary for the years from January 1, 1890, to June 30, 1905, inclusive:

WEATHER SUMMARY FOR JULY, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	73°	63°	68.°	.81	S.	Cloudy.
2	74	55	64.5	.04	S.W.	Clear.
3	72	48	60.	....	N.W.	Clear
4	73	49	61.	....	S.W.	Clear.
5	77	61	69.	.05	S.	Fair.
6	78	62	70.	.15	S.	Cloudy.
7	77	61	69.	.07	S.	Cloudy.
8	77	58	67.5	....	S.E.	Fair.
9	76	53	64.5	....	E.	Clear.
10	77	59	68.	....	Variable.	Fair.
11	81	60	70.5	....	S.W.	Cloudy.
12	77	65	71.	....	S.W.	Fair.
13	80	61	70.5	trace.	N.W.	Fair.
14	80	49	64.5	....	N.W.	Clear.
15	80	57	68.5	....	Variable.	Fair.
16	82	62	72.	....	S.	Fair.
17	83	62	72.5	....	S.W.	Clear.
18	85	61	73.	....	S.	Fair.
19	87	63	75.	....	Variable.	Clear.
20	85	65	75.	....	W.	Clear.
21	82	58	70.	....	W.	Clear.
22	75	60	67.5	.16	E.	Cloudy.
23	63	57	60.	.87	N.E.	Cloudy.
24	66	56	61.	.26	N.	Cloudy.
25	75	60	67.5	....	S.W.	Fair.
26	80	61	70.5	....	S.W.	Fair.
27	79	65	72.	.06	S.W.	Fair.
28	80	62	71.	....	S.W.	Cloudy.
29	80	62	71.	trace.	W.	Fair.
30	75	52	63.5	....	W.	Clear.
31	80	59	69.5	....	S.W.	Fair.
Sum......	2,049	1,826	2,117.5	2.47	....	....
Mean.....	77.7	58.9	68.3	....	....	....

Maximum temperature...........87°. Mean temperature.............68.3°.
Minimum temperature............48°. Prevailing wind...........southwest.

WEATHER SUMMARY FOR AUGUST, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	82°	67°	74.5°	....	S.W.	Cloudy.
2	78	63	70.5	.68	S.W.	Cloudy.
3	80	60	70.	.57	Variable.	Fair.
4	72	60	66.	....	E.	Cloudy.
5	70	61	65.5	....	S.E.	Cloudy.
6	77	65	71.	.97	S.	Fair.
7	83	62	72.5	....	S.W.	Clear.
8	73	62	67.5	....	W.	Fair.
9	72	52	62.	....	Variable.	Clear.
10	69	52	60.5	2.48	E.	Cloudy.
11	82	65	73.5	....	S.W.	Fair.
12	71	55	63.	....	Variable.	Fair.
13	70	53	61.5	....	Variable.	Cloudy.
14	73	59	66.	.19	S.E.	Cloudy.
15	82	56	69.	....	N.W.	Clear.
16	75	59	67.	.16	E.	Cloudy.
17	82	62	72.	....	S.W.	Fair.
18	77	58	67.5	....	N.W	Clear.
19	75	49	62.	....	S.W.	Fair.
20	68	56	62.	2.05	S.	Cloudy.
21	81	62	71.5	....	N.W.	Clear.
22	78	57	67.5	....	S.W.	Clear.
23	75	54	64.5	....	Variable.	Clear.
24	77	49	63.	....	N.W.	Clear.
25	77	57	67.	....	S.W.	Clear.
26	74	54	64.	trace.	W.	Fair.
27	72	45	58.5	....	S.W.	Clear.
28	74	58	66.	....	S.W.	Fair.
29	82	55	68.5	....	W.	Fair.
30	69	55	62.	....	E.	Clear.
31	74	51	62.5	....	Variable.	Clear.
Sum......	2,344	1,763	2,058.5	7.63	....	....
Mean.....	75.6	56.9	66.3	....	....	....

Maximum temperature............83°.
Minimum temperature............45°.
Mean temperature.............66.3°.
Prevailing wind...........southwest.

WEATHER SUMMARY FOR SEPTEMBER, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	70°	50°	60.°	....	S.E.	Fair.
2	80	54	67.	....	S.W.	Clear.
3	81	62	71.5	....	S.W.	Clear.
4	82	60	71.	....	W.	Clear.
5	73	51	62.	....	W.	Fair.
6	67	47	57.	....	Variable.	Clear.
7	70	47	58.5	....	S.W.	Clear.
8	78	49	63.5	.03	S.W.	Fair.
9	59	55	57.	.04	N. E.	Cloudy.
10	70	51	60.5	....	S.	Clear.
11	73	52	62.5	.01	N. E.	Fair.
12	79	63	71.	.06	S.W.	Fair.
13	68	55	61.5	....	E.	Cloudy.
14	70	54	62.	.48	S.	Cloudy.
15	68	47	57.5	.85	N.W.	Fair.
16	67	42	54.5	....	S.W.	Clear.
17	75	51	63.	....	S.W.	Clear.
18	77	56	66.5	....	S.	Clear.
19	77	57	67.	....	Variable.	Fair.
20	70	53	61.5	.07	E.	Cloudy.
21	62	41	51.5	....	N.W.	Clear.
22	54	29	41.5	....	N.	Clear.
23	60	31	45.5	....	W.	Clear.
24	67	44	55.5	....	S.	Cloudy.
25	79	59	69.	.11	S.W.	Fair.
26	70	51	60.5	.02	Variable.	Fair.
27	69	51	60.	....	Variable.	Fair.
28	65	48	56.5	....	S.E.	Fair.
29	67	45	56.	.30	S.	Cloudy.
30	77	55	66.	....	W.	Fair.
Sum......	2,124	1,510	1,817	1.97	....	....
Mean.....	70.8	50.3	60.6	....	....	....

Maximum temperature............82°. Mean temperature.............60.6°.
Minimum temperature............29°. Prevailing wind...........southwest.

WEATHER SUMMARY FOR OCTOBER, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	62°	44°	53°	....	W.	Fair.
2	57	39	48.	....	W.	Fair.
3	62	36	49.	....	W.	Clear.
4	63	35	49.	....	W.	Clear.
5	64	41	52.5	....	S.	Fair.
6	57	37	47.	trace.	N.W.	Fair.
7	52	29	40.5	....	Variable.	Clear.
8	60	32	46.	....	S.	Fair.
9	64	51	57.5	.04	S.W.	Cloudy.
10	65	49	57.	....	S.	Cloudy.
11	75	50	62.5	....	Variable.	Fair.
12	50	40	45.	1.35	N.E.	Cloudy.
13	47	36	41.5	....	N.W.	Cloudy.
14	62	32	47.	....	N.W.	Clear.
15	58	36	47.	....	N.W.	Clear.
16	65	29	47.	....	Variable.	Clear.
17	73	35	54.	....	S.W.	Clear.
18	78	44	61.	....	S.W.	Clear.
19	58	44	51.	....	N.E.	Cloudy.
20	67	49	58.	....	S.	Cloudy.
21	62	46	54.	.72	S.E.	Fair.
22	63	40	51.5	....	S.W.	Clear.
23	58	34	46.	....	S.W.	Clear.
24	53	31	42.	....	W.	Clear.
25	60	34	47.	....	S.W.	Fair.
26	58	41	49.5	.19	W.	Cloudy.
27	48	29	38.5	....	N.W.	Clear.
28	47	23	35.	....	S.E.	Clear.
29	58	35	46.5	....	W.	Clear.
30	47	27	37.	....	N.	Clear.
31	46	20	33.	....	N.W.	Clear.
Sum......	1,839	1,148	1,493.5	2.30	....	....
Mean.....	59.3	37.	48.2	....	....	....

Maximum temperature............78°. Mean temperature.............48.2°.
Minimum temperature............20°. Prevailing wind................west.

WEATHER SUMMARY FOR NOVEMBER, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	54°	29°	41.5°	....	N.W.	Fair.
2	50	28	39.	....	S.E.	Clear.
3	55	38	46.5	....	S.	Fair.
4	57	38	47.5	....	N.E.	Clear.
5	40	27	33.5	....	N.E.	Fair.
6	44	27	35.5	....	W.	Fair.
7	40	26	33.	....	W.	Clear.
8	47	22	34.5	....	W.	Clear.
9	33	29	31.	.42	N.	Fair.
10	48	26	37.	....	W.	Clear.
11	38	26	32.	.06	W.	Fair.
12	48	22	35.	....	S.W.	Clear.
13	44	28	36.	2.10	N.E.	Rainy.
14	42	30	36.	....	N.W.	Fair.
15	49	26	37.5	....	W.	Clear.
16	50	32	41.	....	W.	Fair.
17	34	18	26.	....	W.	Clear.
18	35	12	23.5	....	N.	Clear.
19	53	15	34.	....	W.	Clear.
20	55	33	44.	....	W.	Clear.
21	50	31	40.5	....	W.	Clear.
22	50	21	35.5	....	S.W.	Clear.
23	50	32	41.	....	W.	Fair.
24	46	33	39.5	....	N.W.	Cloudy.
25	42	26	34.	....	N.W.	Fair.
26	41	22	31.5	....	W.	Clear.
27	33	15	24.	.15	N.W.	Fair.
28	29	11	20.	....	N.W.	Clear.
29	49	7	28.	.42	S.	Cloudy.
30	50	36	43.	....	S.W.	Fair.
Sum......	1,356	766	1,061	3.15	....	....
Mean.....	45.2	25.5	35.4	....	....	....

Maximum temperature............57°.
Minimum temperature............ 7°.
Mean temperature.............35.4°.
Prevailing wind................west.

WEATHER SUMMARY FOR DECEMBER, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	38°	22°	30°	trace.	W.	Clear.
2	31	20	25.5	....	W.	Fair.
3	26	19	22.5	....	N.E.	Fair.
4	26	12	19.	....	W.	Fair.
5	32	13	22.5	.40	Variable.	Cloudy.
6	34	16	25.	....	W.	Clear.
7	37	15	26.	....	W.	Fair.
8	31	18	24.5	....	W.	Fair.
9	24	11	17.5	....	W.	Clear.
10	14	5	9.5	.12	N.	Cloudy.
11	20	4	12.	....	W.	Clear.
12	28	7	17.5	.60	N.E.	Cloudy.
13	27	16	21.5	.40	N.	Fair.
14	19	5	12.	....	W.	Clear.
15	26	8	17.	trace.	N.	Fair.
16	32	15	23.5	.30	N.W.	Fair.
17	32	8	20.	....	S.W.	Fair.
18	32	18	25.	.80	N.W.	Fair.
19	40	12	26.	....	S.W.	Cloudy.
20	36	17	26.5	trace.	S.W.	Fair.
21	29	11	20.	....	W.	Clear.
22	29	4	16.5	....	S.W.	Fair.
23	43	29	36.	.05	S.W.	Cloudy.
24	41	18	29.5	trace.	N.W.	Cloudy.
25	22	9	15.5	.10	N.E.	Cloudy.
26	26	14	20.	....	N.E.	Cloudy.
27	47	25	36.	1.65	S.W.	Rainy.
28	50	24	37.	.50	S.W.	Fair.
29	32	18	25.	....	W.	Clear.
30	32	21	26.5	.05	W.	Fair.
31	46	20	33.	....	W.	Fair.
Sum......	982	454	718	4.97	....	....
Mean.....	31.6	14.6	23.1	....	....	....

Maximum temperature...........50°. Mean temperature.............23.1°.
Minimum temperature............ 4°. Prevailing wind................west.

WEATHER SUMMARY FOR JANUARY, 1905.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	49°	32°	40.5°	....	W.	Clear.
2	45	30	37.5	.10	S.W.	Fair.
3	39	19	29.	.42	N.E.	Rainy.
4	19	3	11.	.40	W.	Fair.
5	22	—1	10.5	....	W.	Clear.
6	34	6	20.	.30	N.E.	Cloudy.
7	48	32	40.	1.31	S.W.	Fair.
8	33	24	28.5	....	W.	Clear.
9	35	16	25.5	....	W.	Clear.
10	37	20	28.5	....	S.W.	Fair.
11	32	17	24.5	....	N.W.	Cloudy.
12	46	26	36.	.92	Variable.	Rainy.
13	37	19	28.	....	W.	Cloudy.
14	22	8	15.	....	N.W.	Fair.
15	22	2	12.	....	W.	Clear.
16	29	12	20.5	....	S.W.	Fair.
17	36	15	25.5	....	W.	Clear.
18	38	18	28.	....	W.	Clear.
19	45	23	34.	....	S.W.	Clear.
20	41	26	33.5	....	W.	Clear.
21	39	18	28.5	.04	E.	Cloudy.
22	39	27	33.	.27	W.	Fair.
23	32	10	21.	....	N.W.	Clear.
24	24	7	15.5	.05	N.E.	Fair.
25	24	5	14.5	.55	N.E.	Cloudy.
26	14	3	8.5	....	N.W.	Clear.
27	31	5	18.	....	W.	Clear.
28	33	14	23.5	.01	S.W.	Fair.
29	29	7	18.	....	W.	Clear.
30	22	11	16.5	....	N.	Fair.
31	25	7	16.	....	W.	Clear.
Sum......	1,021	461	741	4.37	....	....
Mean.....	32.9	14.9	23.9	....	....	....

Maximum temperature...........49°. Mean temperature.............23.9°.
Minimum temperature...........—1°. Prevailing wind ....west.

WEATHER SUMMARY FOR FEBRUARY, 1905.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	27°	5°	16.°	....	N.W.	Fair.
2	22	8	15.	....	N.W.	Clear.
3	18	1	9.5	....	N.W.	Clear.
4	19	—4	7.5	....	W.	Clear.
5	29	1	15.	....	S.E.	Fair.
6	33	19	26.	.72	N.E.	Cloudy.
7	28	13	20.5	....	W.	Clear.
8	32	7	19.5	....	N.E.	Clear.
9	32	17	24.5	.53	N.E.	Rainy.
10	38	23	30.5	....	Variable.	Cloudy.
11	27	12	19.5	....	W.	Clear.
12	34	5	19.5	.76	E.	Cloudy.
13	40	12	26.	.05	W.	Cloudy.
14	19	1	10.	....	W.	Clear.
15	26	5	15.5	....	Variable.	Cloudy.
16	19	2	10.5	....	W.	Clear.
17	37	11	24.	....	S.W.	Fair.
18	26	10	18.	....	W.	Clear.
19	22	4	13.	....	W.	Clear.
20	33	15	24.	.12	S.W.	Cloudy.
21	45	29	37.	....	Variable.	Clear.
22	32	19	25.5	....	N.E.	Cloudy.
23	32	17	24.5	....	N.	Clear.
24	40	19	29.5	....	N.W.	Fair.
25	40	18	29.	....	W.	Clear.
26	37	22	29.5	....	S.W.	Fair.
27	29	16	22.5	....	W.	Clear.
28	38	15	26.5	....	W.	Clear.
Sum.....	864	322	588	2.18	....	....
Mean.....	30.5	11.5	21	....	....	....

Maximum temperature..........45°.
Minimum temperature..........—4°.
Mean temperature..........21°.
Prevailing wind..........west.

WEATHER SUMMARY FOR MARCH, 1905.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	32°	17°	24.5°	....	W.	Clear.
2	30	18	24.	....	W.	Clear.
3	36	11	23.5	....	W.	Clear.
4	42	20	31.	....	W.	Fair.
5	28	9	18.5	....	S.W.	Fair.
6	36	18	27.	....	N.W.	Clear.
7	37	17	27.	.22	Variable.	Cloudy.
8	37	30	33.5	.57	S.	Rainy.
9	43	29	36.	.12	Variable.	Rainy.
10	48	30	39.	.36	W.	Fair.
11	35	20	27.5	....	W.	Clear.
12	38	20	29.	....	W.	Fair.
13	37	17	27.	....	W.	Clear.
14	38	18	28.	....	Variable.	Cloudy.
15	38	16	27.	....	W.	Clear.
16	47	21	34.	....	S.W.	Fair.
17	44	25	34.5	....	Variable.	Clear.
18	57	28	42.5	....	S.W.	Clear.
19	48	42	45.	.21	S.W.	Rainy.
20	42	30	36.	.02	N.	Cloudy.
21	33	29	31.	1.06	N.E.	Rainy.
22	37	25	31.	....	N.	Fair.
23	42	23	32.5	....	E.	Clear.
24	43	26	34.5	....	S.E.	Cloudy.
25	48	39	43.5	.21	S.W.	Cloudy.
26	60	36	48.	....	W.	Clear.
27	58	37	47.5	.01	W.	Fair.
28	68	37	52.5	....	W.	Fair.
29	60	40	50.	....	N.E.	Clear.
30	56	36	46.	.05	S.	Fair.
31	67	34	50.5	....	W.	Clear.
Sum......	1,365	788	1,026.5	2.86	....	....
Mean.....	44	25.4	34.7	....	....	....

Maximum temperature............68°.
Minimum temperature............ 8°.
Mean temperature.............34.7°.
Prevailing wind.................west.

WEATHER SUMMARY FOR APRIL, 1905.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	53°	35°	44.°	....	N.W.	Fair.
2	47	24	35.5	....	N.W.	Clear.
3	58	23	40.5	....	N.W.	Clear.
4	47	35	41.	.01	N.E.	Cloudy.
5	50	39	44.5	.44	N.W.	Cloudy.
6	50	36	43.	1.21	S.	Fair.
7	52	27	39.5	....	W.	Clear.
8	50	28	39.	....	W.	Fair.
9	56	26	41.	....	W.	Fair.
10	58	37	47.5	trace.	W.	Fair.
11	54	36	45.	.61	N.E.	Cloudy.
12	56	38	47.	....	N.E.	Fair.
13	49	36	42.5	....	N.E.	Cloudy.
14	60	36	48.	....	S.	Clear.
15	56	33	44.5	.10	N.W.	Clear.
16	50	32	41.	....	W.	Fair.
17	44	24	34.	....	W.	Clear.
18	50	30	40.	....	W.	Fair.
19	51	26	38.5	....	S.W.	Clear.
20	60	35	47.5	.17	S.	Fair.
21	60	42	51.	.27	S.W.	Cloudy.
22	53	36	44.5	....	Variable.	Clear.
23	57	31	44.	....	W.	Clear.
24	55	32	43.5	....	S.W.	Fair.
25	63	41	52.	....	W.	Clear.
26	65	41	53.	....	S.W.	Cloudy.
27	63	46	54.5	.02	Variable.	Fair.
28	59	38	48.5	....	N.E.	Fair.
29	57	36	46.5	....	S.	Cloudy.
30	70	41	55.5	....	W.	Clear.
Sum......	1,653	1,020	1,336.5	2.83	....	....
Mean.....	55.1	34	44.5	....	....	....

Maximum temperature...........70°.
Minimum temperature............23°.
Mean temperature...............44.5°.
Prevailing wind..................west.

WEATHER SUMMARY FOR MAY, 1905.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	55°	36°	45.5°	....	W.	Clear.
2	58	30	44.	....	S.W.	Clear.
3	69	41	55.	....	S.W.	Clear.
4	56	42	50.	....	Variable.	Fair.
5	58	36	47.	....	S.E.	Fair.
6	66	43	54.5	....	S.W.	Cloudy.
7	79	50	64.5	.06	S.W.	Fair.
8	67	43	55.	....	Variable.	Clear.
9	66	40	53.	.15	N.W.	Fair.
10	70	42	56.	....	N.W.	Fair.
11	72	45	58.5	....	S.W.	Clear.
12	63	48	55.5	.53	S.W.	Cloudy.
13	60	45	52.5	....	E.	Cloudy.
14	59	45	52.	.62	Variable.	Cloudy.
15	73	51	62.	....	S.E.	Cloudy.
16	53	43	48.	.07	N.E.	Cloudy.
17	49	42	45.5	....	N.E.	Cloudy.
18	65	42	53.5	.08	S.W.	Fair.
19	68	47	57.5	....	W.	Clear.
20	56	46	51.	....	W.	Clear.
21	63	37	50.	....	S.W.	Clear.
22	70	39	54.5	....	S.W	Clear.
23	63	47	55.	.03	N.	Cloudy.
24	65	38	51.5	....	S.W.	Clear.
25	66	44	55.	....	S.W.	Clear.
26	72	52	62.	....	S.W.	Clear.
27	69	55	62.	.04	S.W.	Cloudy.
28	80	58	69.	....	S.W.	Clear.
29	79	54	66.5	....	W.	Fair.
30	67	50	58.5	.11	N.E.	Fair.
31	69	48	58.5	....	E.	Clear.
Sum......	2,027	1,379	1,703	1.69	....	....
Mean.....	65.4	44.5	55.	....	....	....

Maximum temperature...........80°.
Minimum temperature............30°.
Mean temperature...............55°.
Prevailing wind...........southwest.

WEATHER SUMMARY FOR JUNE 1905.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	64°	47°	55.5°	....	N.E.	Fair.
2	72	42	57.	.03	S.W.	Fair.
3	72	49	50.5	....	W.	Clear.
4	74	44	59.	....	S.W.	Fair.
5	79	54	66.5	....	S.W.	Cloudy.
6	72	49	60.5	1.04	N.E.	Cloudy.
7	56	45	50.5	.05	N.E.	Cloudy.
8	54	44	49.	.22	N.	Fair.
9	72	38	55.	....	Variable.	Clear.
10	79	49	64.	....	S.W.	Clear.
11	69	51	60.	....	S.W.	Cloudy.
12	62	56	59.	2.15	S.W.	Cloudy.
13	74	56	65.	.34	S.W.	Cloudy.
14	81	59	70.	....	S.W.	Clear.
15	85	60	72.5	....	S.W.	Clear.
16	82	56	69.	....	S.W.	Clear.
17	77	57	67.	....	S.W.	Clear.
18	83	61	72.	....	S.W.	Fair.
19	68	51	59.5	.52	N.E.	Cloudy.
20	58	49	53.5	....	N.E.	Cloudy.
21	65	53	59.	.74	E.	Cloudy.
22	78	57	67.5	.13	W.	Fair.
23	81	63	72.	....	Variable.	Cloudy.
24	77	59	68.	....	S.W.	Fair.
25	80	53	66.5	....	S.W.	Clear.
26	82	56	69.	....	S.W.	Fair.
27	71	51	61.	....	N.W.	Clear.
28	74	47	60.5	....	N.W.	Clear.
29	80	53	66.5	....	W.	Clear.
30	82	55	68.5	....	S.W.	Clear.
Sum......	2,203	1,564	1,883.5	5.22	....	....
Mean.....	73.4	52.1	62.8	....	....	....

Maximum temperature...........85°. Mean temperature...............62°.
Minimum temperature............38°. Prevailing wind...........southwest.

SUMMARY JANUARY 1, 1890, TO JUNE 30, 1905. INCLUSIVE.

	Maximum temperature.	Minimum temperature.	Mean temperature.	Number of clear days.	Partly cloudy days.	Cloudy days.	Days with .01 inch or more of precipitation.	Total precipitation, inches.
1890	91°	3°	48.3°	99	143	123	120	59.25
1891	94	5	49.4	116	154	95	83	49.88
1892	92	—1	47.8	147	116	103	89	42.58
1893	92	—6	46.5	126	130	109	131	57.33
1894	93	—9	48.6	110	130	125	114	48.19
1895	95	—7	48.2	128	114	123	108	49.28
1896	93	—11	47.7	131	112	123	109	49.87
1897	90	—1	48.3	129	126	110	128	54.25
1898	95	—4	48.8	110	114	141	131	72.21
1899, January 1 to June 30	95	—10	42.1	77	44	60	59	26.79
July 1, 1899, to June 30, 1900	90	—5	48.3	141	113	111	102	51.67
July 1, 1900, to June 30, 1901	97	—9	48.4	134	97	134	114	48.47
July 1, 1901, to June 30, 1902	93	—1	48.0	138	116	111	109	53.14
July 1, 1902, to June 30, 1903	90	—12	48.3	138	96	131	103	59.27
July 1, 1903, to June 30, 1904	93	—16	45.7	156	107	103	118	50.06
July 1, 1904, to June 30, 1905	87	—4	45.3	151	122	92	99	41.64

Average temperature for 15½ years........................46.4°.
Average precipitation for 15½ years..................52.51 inches.

REPORT OF THE TREASURER.

The Rhode Island Agricultural Experiment Station, *in account with the* United States Appropriation, 1904–1905.

1905.	Dr.		
	To receipts from the treasurer of the United States as per appropriation for fiscal year ended June 30, 1905, as per act of Congress approved March 2, 1887		$15,000 00
1905.	Cr.		
	By Salaries	$9,377 76	
	Labor	1,854 43	
	Publications	45 67	
	Postage and stationery	144 76	
	Freight and express	109 40	
	Heat, light, water, and power	373 36	
	Chemical supplies	53 66	
	Seeds, plants, and sundry supplies	287 72	
	Fertilizers	169 03	
	Feeding-stuffs	645 80	
	Library	362 33	
	Tools, implements, and machinery	192 50	
	Furniture and fixtures	25 86	
	Live stock	432 50	
	Traveling expenses	268 39	
	Contingent expenses	15 00	
	Buildings and repairs	641 83	
			$15,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Rhode Island Agricultural Experiment Station for the fiscal year ended June 30, 1905; that we have found the same well kept and classified as above, and that the receipts for

the year from the treasurer of the United States are shown to have been $15,000, and the corresponding disbursements $15,000, for all of which proper vouchers are on file, and have been examined by us and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress approved March 2, 1887.

CHARLES DEAN KIMBALL,
C. H. COGGESHALL,
Auditors.

Melville Bull, *Treasurer, in account with the* Rhode Island Agricultural Experiment Station, *for the year ended June* 30, 1905.

1905.	Dr.	
	To Balance from last year	$2,611 31
	Station receipts	1,028 81
	Interest	98 33
		$3,738 45

1905.	Cr.	
	By Labor	$318 17
	Publications	3 08
	Postage and stationery	7 62
	Chemical supplies	14 53
	Seeds, plants, and sundry supplies	25 92
	Fertilizers	4 50
	Feeding-stuffs	46 65
	Library	3 60
	Tools, implements, and machinery	37 66
	Furniture and fixtures	1 10
	Scientific apparatus	1 50
	Traveling expenses	25 35
	Contingent expenses	13 15
	Buildings and repairs	18 71
	Balance	3,216 91
		$3,738 45

This certifies that we, the undersigned, auditing committee of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts, have examined the accounts of Melville Bull, treasurer of the Rhode Island Agricultural Experiment Station, and find the same correct.

The total receipts were $3,738.45, and the total expenditures were $621.54, thus leaving a balance to new account of $3,216.91.

CHARLES DEAN KIMBALL,
C. H. COGGESHALL.

Auditors.

EXCHANGES.

Aboriculture, Connersville, Ind.
Agricultural Advertising, Pittsburg, Pa.
Agricultural Epitomist, Spencer, Ind.
Agricultural Gazette of New South Wales, Australia.
Agricultural Ledger, Calcutta, India.
American Cultivator, Boston, Mass.
American Fancier, Johnstown, N. Y.
American Fertilizer, Philadelphia, Pa.
American Hay, Flour, and Feed Journal, New York.
American Horse Breeder, Boston, New York, and Chicago.
American Nut Journal, Petersburg, Va.
American Philosophical Society, Proceedings of the Society.
American Poultry Advocate, Syracuse, N. Y.
American Poultry Journal, Chicago, Ill.
American Sheep Breeder and Wool Grower, Chicago, Ill.
American Stock Farm, The, Winona, Minn.
American Stock Keeper, Boston, Mass.
American Sugar Industry and Beet Sugar Gazette, Chicago, Ill.
Breeders' Gazette, Chicago, Ill.
Bulletins of the Botanical Department of Jamaica, and Reports of Public Gardens and Plantations.
Bulletins of the New York State Museum.
California Cultivator, Los Angeles, Cal.
Chicago Daily Drovers' Journal, Chicago, Ill.
Colman's Rural World, St. Louis, Mo.
Connecticut Farmer, New Haven, Conn.
Corbett's Herald, Providence, R. I.

Current Numbers of Minnesota Botanical Studies, University of Minnesota.
Elgin Dairy Report, Elgin, Ill.
Evening Telegram, Providence, R. I.
Farm and Fireside, Springfield, Ohio.
Farm and Live Stock Journal, Detroit, Mich.
Farm, Field, and Fireside, Chicago, Ill.
Farm Home, The, Springfield, Ill.
Farm Journal, Philadelphia, Pa.
Farm Life, Chicago, Ill.
Farm Poultry, Boston, Mass.
Farm, Stock, and Home, Minneapolis, Minn.
Farmers' Advocate, London, Ontario.
Farmers' Guide, Huntington, Ind.
Farmers' Review, The, Chicago, Ill.
Farmers' Sentinel, Milwaukee, Wis.
Farmers' Tribune, Des Moines, Iowa.
Feather, The, Washington, D. C.
Feathered World, The, London, England.
Flour and Feed, Waukegan, Ill.
Fruit Grower, The, St. Joseph, Mo.
Geflugel-Buchter, Hamburg, Wis.
Hoard's Dairyman, Fort Atkinson, Wis.
Holstein-Fresian Register, Brattleboro, Vt.
Homestead, The, Des Moines, Iowa.
Hope Valley Free Press, Hope Valley, R. I.
Hospodarske Listy, Chicago, Ill.
Indiana Farmer, Indianapolis, Ind.
Inland Poultry Journal, Indianapolis, Ind.
Journal Royal Horticultural Society, London, England.
Kansas Farmer, Topeka, Kansas.
Kimball's Dairy Farm, Waterloo, Iowa.
Maryland Agricultural Quarterly, College Park, Md.
Massachusetts Ploughman, Boston, Mass.

Metropolitan and Rural Home, The, New York City.
Miscellaneous Publications, Department of Agriculture and Mines, Natal, Africa.
Modern Farmer and Busy Bee, The, St. Joseph, Mo.
Missouri Agricultural College Farmer, Columbia, Mo.
National Stockman and Farmer, Pittsburg, Pa.
Nebraska Farmer, Omaha, Neb.
New England Farmer, Brattleboro, Vt.
New England Homestead, Springfield, Mass.
New Farm, Preston, Md.
New Hampshire Farmer and Weekly Union, Manchester, N. H.
Northwest Horticulturist, Tacoma and Seattle, Wash.
Nut Grower, The, Poulan, Ga.
Ohio Farmer, Cleveland, Ohio.
Oregon Agriculturist, Portland, Oregon.
Orff's Farm and Poultry Review, St. Louis, Mo.
Poultry, Peotone, Ill.
Poultry Gazette, Kansas City, Kansas.
Poultry Herald, St. Paul, Minn.
Poultry Item, Fricks, Pa.
Poultry Standard, Stamford, Conn.
Poultry Success, Des Moines, Iowa.
Poultry Topics, Lincoln, Neb.
Practical Farmer, The, Philadelphia, Pa.
Practical Fruit Grower, Springfield, Mo.
Prairie Farmer, The, Chicago, Ill.
Providence News, The, Providence, R. I.
Publications of the Florida Department of Agriculture.
Publications of the Department of Agriculture, Mysore State, India.
Publications of the Imperial Agricultural Experiment Station, Nishigahara, Tokyo, Japan.
Publications of the Maine State Board of Agriculture.
Publications of the Massachusetts State Board of Agriculture.
Publications of the Department of Agriculture, New Zealand.

Publications of the North Carolina State Board of Agriculture.
Publications of the Department of Agriculture, University College, North Wales.
Publications of the Ohio State Board of Agriculture.
Publications of the Pennsylvania Department of Agriculture.
Publications of the Rhode Island State Board of Agriculture.
Publications of the Department of Agriculture, Victoria.
Publications of the Virginia Department of Agriculture.
Publications of the Department of Agriculture of Western Australia.
Queensland Agricultural Journal, Australia.
Reliable Poultry Journal, Quincy, Ill.
Republic, The, St. Louis, Mo.
Rock Products, Louisville, Ky.
Rural New-Yorker, New York City.
Rural World, London, England.
Skandinavisk Farmer Journal, Minneapolis, Minn.
Southern Fancier, Atlanta, Ga.
Southern Planter, Richmond, Va.
Successful Farming, Des Moines, Iowa.
Successful Poultry Journal, Chicago, Ill.
Sugar Beet, The, Philadelphia, Pa.
Sec. da Agr. Estado de São Paulo, Boletim da Agriculture.
Texas Farmer, Dallas, Texas.
Transvaal Agricultural Journal, India.
Up-to-Date Farming and Gardening, Indianapolis, Ind.
Wallace's Farmer, Des Moines, Iowa.
Western Fruit Grower, St. Joseph, Mo.
W. Weedel & Co.'s Colonial Dairy Produce Report, London, England.
West Virginia Farm Review, Charleston, W. Va.
Wilson Bulletins, Wilson Ornithological Club, Oberlin, Ohio.
Wisconsin Agriculturist, Racine, Wis.
Yearbook and Current Publications der Deutschen Landwirtschafts-Gesellschaft.

Directions for Binding the Bulletins and Reports of the Rhode Island Experiment Station.

Vol.	1-3*,	Bulletins	1-9,	Reports,	1-3,	1888-1890.
"	4,	"	10-14,	Report,	4,	1891.
"	5,	"	15-20,	"	5,	1892.
"	6,	"	21-26,	"	6,	1893.
"	7,	"	27-30,	"	7,	1894.
"	8,	"	31-35,	"	8,	1895.
"	9,	"	36-42,	"	9,	1896.
"	10,	"	43-46,	"	10,	1897.
"	11,	"	47-51,	"	11,	1898.
"	12,	"	52-55,	"	12,	1899.
"	13,	"	56-69,	"	13,	1899-1900.
"	14,	"	70-78,	"	14,	1900-1901.
"	15,	"	79-86,	"	15,	1901-1902.
"	16,	"	87-94,	"	16,	1902-1903.
"	17,	"	95-101,	"	17,	1903-1904.
"	18,	"	102-107,	"	18,	1904-1905.

* Vols. 1-3 in one cover. Beginning with volume 4, a title page and index for each volume is to be found at the end of the annual report for each year. The year covered by a volume formerly was the calendar year, but now it extends from July 1 to June 30. Each volume, beginning with volume 4, is paged separately. The Bulletins of a given year precede the Report, and the latter is paged in continuation of the last Bulletin belonging in the volume.

BULLETINS

AND

ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDING JUNE 30,

1905.

PROVIDENCE:
E. L. FREEMAN & SONS, STATE PRINTERS
1906.

INDEX

OF THE

BULLETINS AND ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDING JUNE 30, 1905.

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NOTE.—For pp. 1–14 see Bul. 102; for pp. 15–46 see Bul. 103; for pp. 47–92 see Bul. 104; for pp. 93–108 see Bul. 105; for pp. 109–154 see Bul. 106; for pp. 155–168 see Bul. 107.

Note.—For pp. 1–14 see Bul. 102; for pp. 15–46 see Bul. 103; for pp. 47–92 see Bul. 104; for pp. 93–108 see Bul. 105; for pp. 109–154 see Bul. 106; for pp. 155–168 see Bul. 107.

NOTE.—For pp. 1–14 see Bul. 102; for pp. 15–46 see Bul. 103; for pp. 47–92 see Bul. 104; for pp. 93–108 see Bul. 105; for pp. 109–154 see Bul. 106; for pp. 155–168 see Bul. 107.

Note.—For pp. 1–14 see Bul. 102; for pp. 15–46 see Bul. 103; for pp. 47–92 see Bul. 104; for pp. 93–108 see Bul. 105; for pp. 109–154 see Bul. 106; for pp. 155–168 see Bul. 107.

NOTE.—For pp. 1–14 see Bul. 102; for pp. 15–46 see Bul. 103; for pp. 47–92 see Bul. 104; for pp. 93–108 see Bul. 105; for pp. 109–154 see Bul. 106; for pp. 155–168 see Bul. 107.

Agricultural Experiment Station, 1906

PART II
NINETEENTH ANNUAL REPORT.

FORMAL REPORT OF THE BOARD OF MANAGERS IS PART I.

COLLEGE CATALOGUE IS PART III.

Kingston,

R. I.

State of Rhode Island and Providence Plantations.

NINETEENTH ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

1905-1906.

PART II.

OF THE

NINETEENTH ANNUAL REPORT

OF THE

CORPORATION, BOARD OF MANAGERS

OF THE

Rhode Island College of Agriculture and Mechanic Arts,

MADE TO THE

GENERAL ASSEMBLY AT ITS JANUARY SESSION, 1907.

[PARTS I. AND III. OF THIS REPORT — REPORT OF PRESIDENT AND BOARD OF MANAGERS AND COLLEGE CATALOGUE — ARE PRINTED UNDER SEPARATE COVERS.]

PROVIDENCE, R. I.:
E. L. FREEMAN COMPANY, PRINTERS TO THE STATE.
1907.

BOARD OF MANAGERS

OF THE

RHODE ISLAND

College of Agriculture and Mechanic Arts.

CHAS. DEAN KIMBALL, *President*, - - - -	Providence Co., Providence, R. I.
ROBERT S. BURLINGAME, *Vice-President*, - -	Newport Co., Newport, R. I.
C. H. COGGESHALL, *Clerk and Treasurer*, - - - -	Bristol Co., Bristol, R. I.
THOMAS G. MATHEWSON, - - - - - - -	Kent Co., East Greenwich, R. I.
J. V. B. WATSON, - - - - - - - - - - -	Washington Co., Wakefield, R. I.

EXPERIMENT STATION COUNCIL.

KENYON L. BUTTERFIELD, A. M., - - - - - -	President of the College. *Ex-officio* Member.
H. J. WHEELER, Ph. D., - - - - - -	Director, Chemistry and Agronomy.
FRED W. CARD, M. Sc., - - - - - - - - - - - - - - - - -	Horticulture.
COOPER CURTICE, D. V. S., M. D., - - - - - - - -	Animal Husbandry.
BURT L. HARTWELL, Ph. D., - - - - - - - - - - -	Associate, Chemistry.
GEORGE E. ADAMS, B. Sc., - - - - - - - - - - -	Associate, Agronomy.
H. L. BARNES, B. Sc., - - - - - - - - - - - - -	Assistant, Horticulture.
W. F. KIRKPATRICK,* B. Agr., B. E., - - -	Assistant, Animal Husbandry.
A. W. RICHARDSON, B. Sc., - - - - - - - - - - - -	Assistant, Agronomy.

OTHER MEMBERS OF THE STATION STAFF.

P. H. WESSELS, B. Sc., - - - - - - - - - - - - -	Assistant, Chemistry.
F. L. YEAW,† B. Sc., - - - - - - - - - - - - - -	Assistant, Chemistry.
J. FRANK MORGAN, M. A., - - - - - - - - - - - -	Assistant, Chemistry.
F. G. KEYES, B. Sc., - - - - - - - - - -	Temporary Assistant, Chemistry.
NATHANIEL HELME, - - - - - - - - - - - - - - - - - -	Meteorology.
BEULAH A. HOITT, - - - - - - - - - - -	Stenographer and Accountant.
E. ELIZABETH MEEARS, - - - - - - - - -	Stenographer and Librarian.

The publications of the Station will be mailed free on request to any one in Rhode Island interested in agriculture. The Station desires the co-operation of the farmers of the State in the work of investigation, and any facts of special interest concerning animal or vegetable growth or disease are solicited. Visitors are always welcome. Railway station, telegraph, express, and post-office—Kingston Rhode Island. Long distance telephone, Narragansett Pier exchange.

*Expert in the Bureau of Animal Industry, U. S. Department of Agriculture. Engaged in co-operative work between the Bureau and the Station.

†Appointed special agent in the Bureau of Soils, U. S. Department of Agriculture, Washington, D. C. Engaged in co-operative work between the Bureau and the Station.

LETTER OF TRANSMITTAL.

To His Excellency, James H. Higgins, Governor, and the Honorable the General Assembly of the State of Rhode Island, at its January Session, 1907.

KINGSTON, R. I., January 1, 1907.

I have the pleasure to present herewith, in compliance with the statute of the State and the Congressional act of March 2, 1887, the Report of the Director of the Rhode Island Agricultural Experiment Station for the year ended June 30, 1906.

Respectfully submitted,

For the Board of Managers,

CHARLES DEAN KIMBALL,

President.

AGRICULTURAL EXPERIMENT STATION

OF THE

RHODE ISLAND COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

KINGSTON, R. I., June 30, 1906.

HON. CHARLES DEAN KIMBALL,

President, Board of Managers.

SIR:—I have the honor to transmit herewith the Nineteenth Annual Report of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1906.

Respectfully yours,

H. J. WHEELER,

Director.

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DIRECTOR'S REPORT.

REPORT OF THE DIRECTOR.

KINGSTON, R. I., August 15, 1906.

To Honorable Charles Dean Kimball, President of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts.

SIR:—Below will be found a report concerning the work of the Experiment Station for the year ended June 30, 1906.

DIVISION OF CHEMISTRY.

The Division of Chemistry has continued the collection and analysis of commercial fertilizers and commercial feeding-stuffs. Two Bulletins have been published during the year on fertilizers, and one on feeding-stuffs.

It is believed that the publication of these analyses, especially the latter, has exerted an especially beneficial influence, and the correspondence with manufacturers whose goods were found to be faulty has in most cases resulted in immediate steps being taken to correct the condition.

That such efforts are necessary in order to keep the goods up to a proper standard must be evident to anyone who examines with care the recent Bulletin No. 112.

Aside from the routine analytical work in connection with other divisions, the most important analyses of the year have been made in connection with the study of the assimilability or actual agricultural value of organic nitrogen derived from a considerable number of different sources, and in the course of the study of the functions, and the agricultural value, of certain sodium salts.

In all the work of the division I have been ably assisted by Doctor Hartwell, who has had the entire responsibility for all of the laboratory details and for the continuation of the work on the assimilability of nitrogen.

Further details concerning special work of the Chemical Division can be found in an article on the sodium investigations, which is to be found in the subsequent pages.

DIVISION OF HORTICULTURE.

The Horticultural Division has continued the experiments outlined in my report of the previous year. In addition an experiment has been begun for the purpose of testing various individual grasses, mixtures of grasses, and combinations of certain grasses with common white clover, in order to ascertain their relative adaptability for ordinary lawns, golf links, and polo grounds. In connection with this trial it is designed to test the influence of various manurial combinations upon the permanence of the clover and of the several grasses.

Further details of the work of the division may be found embodied in the special report of the Horticulturist, Professor Card, which is to be found in the subsequent pages.

DIVISION OF AGRONOMY.

The general work of the Division of Agronomy has been continued in essentially the lines laid down in my former report. It consists in the study of seven different rotations of crops, a trial of the relative efficiency of several different phosphatic manures, a study of the agricultural value of sodium salts, the influence of lime upon the growth of miscellaneous plants, the most economical mixtures of manures for use in grass culture, the efficiency of Peruvian guano for grass and certain hoed crops, variety tests of early field corn and of potatoes, experiments in continuous corn and grass culture, and tests of various fungicides and insecticides.

My associate in this work, Mr. George E. Adams, has entire charge of all the details, and has carried on independently the experiments with potato varieties, potato spraying, and fungicides.

DIVISION OF ANIMAL HUSBANDRY.

The energies of the Division of Animal Husbandry, which is under the direction of Doctor Curtice, have been devoted, as heretofore, to questions of incubation and brooding, in connection with ordinary fowl. In addition experiments have been begun with guinea fowl, and pheasants, in the same direction. At the same time it was hoped to learn some of the causes of the losses of young pheasants, to study the methods of avoiding loss, and to ascertain if these two kinds of birds are immune to the blackhead disease (*Entero-hepatitis*, Smith) which is so fatal to the turkeys.

The chief work of the division has been in ascertaining, if possible under what conditions turkeys could be reared successfully, the means by which the black-head disease is communicated, and how it can be most successfully combated.

In this connection the attempt is being made, in coöperation with the Bureau of Animal Industry of the U. S. Department of Agriculture, to ascertain if wild turkeys are immune to the disease and if it is not possible to breed immune birds which shall possess high economic value for various purposes.

Great difficulty has been experienced in securing wild stock, owing to the fact that in several states and territories the laws prohibit the exportation of the live birds. Nevertheless the local laws permit the shooting of wild turkeys for several weeks during the year. In order to meet this difficulty it has become necessary to appeal to the local authorities to take steps to have the laws modified so as to permit the capture of wild turkeys in limited numbers for scientific breeding purposes. Owing to the fact that the legislatures in most cases meet only biennially, much time and patience is required to secure help by way of local legislation.

Doctor Curtice now has a Bulletin in preparation which will set forth some of the results obtained in connection with the turkey work, and during the coming year it is hoped that additional matter concerning turkeys, and also the results of the unpublished work on incubation and brooding, may be issued.

THE ADAMS ACT.

Through the energy of the late Hon. H. C. Adams, Representative in Congress from Wisconsin, aided by the farmers' organizations throughout the United States, an act was passed by Congress, on March 16, 1906, increasing the appropriation for each Agricultural Experiment Station in the United States $5,000 for the fiscal year ending June 30, 1906; $7,000 for the following fiscal year, and so on until the additional annual appropriation shall reach the sum of $15,000; or in other words until the total annual appropriation including the fund derived from the Hatch act, shall reach the sum of $30,000 per annum.

Under a subsequent ruling of the Comptroller of the Treasury it was held that the first appropriation was not legally made to begin before the fiscal year beginning July 1, 1906. In view of this a rider was attached to the Agricultural Appropriation bill, interpreting the act in such a way as to make the fund available from and after March 16, 1906. This bill was not, however, passed until a day or two before the close of the fiscal year, on which account, due to the lapsing of the fund on June 30 if unexpended, some of the Stations are likely to lose the whole or a part of the first year's appropriation. By the passage of this act this Station will have at disposal for the coming year the sum of $22,000 for experimental purposes, in addition to aid by way of coöperation on the part of the Bureau of Animal Industry of the U. S. Department of Agriculture to the extent of $2,150 and on the part of the Bureau of Soils to the extent of furnishing two men for several months for investigation work.

Under the interpretation of the authorities in Washington the

Adams fund can be applied only to paying the necessary expenses of conducting *original researches or experiments bearing directly on the agricultural industry of the United States. Expenses for administration, care of buildings and grounds, insurance, office furniture and fittings, demonstration and institute work, and travelling in connection with administration duties, the printing and issuing of bulletins and reports, can not be paid from this fund.*

NEEDS OF THE STATION.

Owing to the increased need of laboratory and office room in consequence of the passage of the Adams act, it will probably soon become necessary for the College to withdraw entirely from the Station building. Heretofore one of the rooms has heen used exclusively as an agricultural lecture room and another has been used for a portion of the time as a physical soil laboratory and geological lecture room. In addition, also, Mr. Stene, who is in charge of the extension and demonstration work of the College, has maintained his office in the building and also the heads of the Divisions of Agronomy and Animal Husbandry of the College.

A most pressing need at the present time is a suitable fire and moisture proof storage vault, in which all of the records of the experimental work can be kept. The present safe is practically full, and, furthermore, it does not afford proper protection in case of fire.

It is obviously undesirable to accumulate experimental data, secured at a cost of many thousands of dollars per year, without providing a place where they can be secure from the danger of fire. In addition to the storage vault there should be provided a suitable office for the Director, where it is possible to do consecutive work without the continual disturbance which results when he is obliged to do all of his work, as at present, in the chief business office of the Station, which must of necessity be always open to the Station staff and to the public. In this particular it is a matter of economy to furnish the same facilities for writing and executive work which are provided

in every well-ordered business office and which are usually found in other experiment stations.

It is of vital importance to the Station at this time that additional land should be set aside for use in connection with the experiments in agronomy and horticulture.

Publications of the Year.

The following is a list of the publications issued during the year:

Eighteenth Annual Report. pp. 179 to 352.

Bulletin No. 108, "Analyses of Commercial Fertilizers." 12 pp.

Bulletin No. 109, "A Comparison of the Results Obtained by the Method of Cultures in Paraffined Wire Pots with the Field Results on the Same Soil.". 22 pp.

Bulletin No. 110, "Commercial Fertilizers." 16 pp.

Bulletin No. 111, "Potatoes." 16 pp.

Bulletin No. 112, "Commercial Feeding-Stuffs." 22 pp.

Bulletin No. 113, "Continuous Corn Culture." 18 pp.

Bulletin No. 114, "A Test of Nine Phosphates with Different Plants." 23 pp.

Changes in the Station Staff.

On August 21, Mr. W. F. Kirkpatrick, B. Agr., B. E., a graduate of the North Carolina College of Agriculture and Mechanic Arts, was appointed expert in the Bureau of Animal Husbandry of the U. S. Department of Agriculture. He was then detailed to assist in the work conducted here in turkey breeding, in which the Bureau and Station are coöperatively engaged.

On September 1, Mr. George E. Adams, B. Sc., formerly assistant in agronomy was made associate agronomist.

Mr. James W. Kellogg, B. Sc., who had served most acceptably as assistant chemist at the Station for about three years, resigned in January, 1906, to accept a position as chemist in Atlanta, Ga.

On June 5, Mr. Matthew Steel, M. Sc., who had been employed at the Station under appointment as expert in the Bureau of Soils of

U. S. Department of Agriculture in coöperative chemical work concerning the action of sodium salts upon soils and plants, tendered his resignation in order to take up advanced studies at Columbia College, New York. Mr. J. P. Gray, B. Sc., who had been connected with the Station as assistant chemist, also tendered his resignation, which went into effect on June 9.

The position as stenographer and librarian, made vacant by the resignation of Miss Martha Vickery at the close of the previous fiscal year, was filled by the appointment of Miss Alethea R. Puffer, A. B., a graduate of Mt. Holyoke College, who in turn resigned, on February 1, 1906, to accept a more lucrative position elsewhere. Subsequently Miss E. Elizabeth Meears was appointed to the position thus made vacant.

On April 1, Mr. F. L. Yeaw, B. Sc., a graduate of the Massachusetts Agricultural College, was appointed assistant in agronomy. Early in May, 1906, he was appointed expert in the Bureau of Soils of the U. S. Department of Agriculture and was detailed to this Station to assist in coöperative soil tests in which the Bureau was lending the Station its aid.

Mr. A. W. Richardson, B. Sc., a graduate of the Maine State University, was appointed assistant in agronomy on April 22, 1906.

On May 7, Mr. J. F. Morgan, M. Sc., a graduate of St. Lawrence University, was appointed assistant chemist; and on June 1, Mr. Fred G. Keyes, who was about to graduate with the degree of B. Sc. from the Rhode Island College of Agriculture and Mechanic Arts, was appointed temporary assistant in chemistry.

On October 1, 1905, M. A. Blake, B. Sc., who had served most acceptably as assistant horticulturist, resigned to accept a more remunerative position elsewhere, and H. L. Barnes, B. Sc., was appointed in his place.

COÖPERATIVE WORK.

The work on soils and in the breeding of turkeys in coöperation

with the Bureau of Soils and the Bureau of Animal Industry of the U. S. Department of Agriculture has been continued, and it is hoped the coming autumn or winter to publish two or more bulletins giving an account of some of the results thus far secured.

ACKNOWLEDGMENTS.

It gives me pleasure to acknowledge the loyal aid of Doctors Curtice and Hartwell, also of Professors Card and Adams, in carrying forward the work of the year. To Doctor Hartwell I am especially indebted for aid in the correction of manuscript and proof sheets. To the other members of the Station staff, whom it would be a pleasure to mention individually, a very large measure of credit is due for daily duties faithfully performed, and all are to be commended for the most admirable spirit of loyalty to the Station, for their continued devotion to its best interest, and for their attitude, by which the relations of one with another have been pleasant and thus conducive to good work and to the general credit of the Station.

HORTICULTURAL DIVISION.

REPORT OF THE HORTICULTURAL DIVISION.

FRED W. CARD, M. A. BLAKE, AND H. L. BARNES.

Destroying Charlock in Grain Fields.

The charlock, or wild radish, forms one of the most troublesome pests in grain fields in this region.

As a part of his student-investigation work in the College, Mr. A. E. Wilkinson, one of our agricultural students, undertook to determine the effect of spraying a field of oats and peas badly infested with charlock. Two solutions were used: one containing 60 pounds of copperas (iron sulfate) to 40 gallons of water, the other containing 12 pounds of blue vitriol (copper sulfate) to 40 gallons of water. A potato sprayer was used in this work. The copper sulfate was applied June 8, the iron sulfate June 14. The charlock was then in bloom, and too tall to be effectually reached by the spray with the machine used.

On June 14, when the copperas was applied, the part previously sprayed with copper sulfate showed that the charlock leaves were apparently killed where hit by the spray. Many of the buds and blooms were also killed. Tips of many of the oat leaves were also killed, and some leaves of the peas were hurt, usually the lower ones. The injury did not appear to be serious enough to materially check the growth of the oats or peas. The spraying seemed to be even more effective in destroying a common weed, resembling smartweed, belonging to the genus *Polygonum*, which was abundant in the field. The plants of this weed were still small, and the leaves appeared to be easily killed by the spray. Later observations proved that the charlock had been well killed out in lines across the field where it had been

struck by the spray. A machine working further from the ground would have been more effective at that time.

In the portion sprayed with copperas (iron sulfate) the oats and peas appeared to be injured more than the charlock. Some charlock leaves were killed, but not enough to prevent its blossoming in a normal manner. The peas in particular had many of the lower leaves blackened and killed. Many of the tops of the oats were also killed.

At the time the oats and peas were harvested for hay the charlock was very little in evidence, apparently having been considerably reduced by the spraying. Judging by this experience, a spray of copper sulfate in the strength here used, if applied in the earlier stages of growth, when the plants could be more effectually reached, would prove decidedly effective in destroying this plant, with no permanent injury to the grain crop.

GRAFTING-WAX.

In the spring of 1905 a number of formulas for making grafting-wax were tried in the laboratory. We were led to do this from getting a lumpy wax in some cases. The chief object was to determine the cause of this lumpy condition.

A Common Wax.

4 lbs. resin.
2 lbs. beeswax.
1 lb. tallow

This is a common formula and gives an excellent wax, very smooth, but rather too hard when it cools. Adding a little tallow to this softens it without making it lumpy.

A Wax With Less Resin.

3 lbs. resin.
3 lbs. beeswax.
2 lbs. tallow.

Although recommended by high authority as excellent, in our experience this formula made a very sticky, lumpy wax, being soft but so sticky that it could hardly be worked at all. Adding more resin improved it, taking away the stickiness and most of the lumps. Adding tallow made it very sticky and lumpy again, so much so that it could not be worked.

An Oil Wax.

4 lbs. resin.
2 lbs. beeswax.
1 pint linseed oil.

This gave a soft, sticky, and very lumpy wax. Adding resin took away the stickiness and nearly all the lumps, making it smooth but hard. The addition of more oil, after extra resin had already been added, made it softer but retained the smoothness and freedom from lumps. The addition of beeswax to this lumpy wax made from oil did not change it to any extent.

A Smaller Proportion of Oil.

100 grams resin.
50 grams beeswax.
20 grams linseed oil.

This makes a soft pliable wax, appearing somewhat dry and a little granular, but hardening into a very nice wax. It is not so hard as the 4–2–1 tallow wax, but is possibly a little too hard for most convenient use.

Resin 4, paraffine 2, oil 1 (by weight), made a lumpy wax, apparently too soft.

Resin 4, paraffine 2, tallow 1, gave a very nice, soft, white wax, but with a few lumps. This would break when first being worked, and was too soft and sticky. It would probably run with heat.

A mixture of resin and tallow alone gave a very lumpy wax, sticky and ductile.

Two parts resin to one part beeswax seems to be the best proportion to use. More or less tallow or oil can be used to render the wax harder or softer as desired. Adding tallow to a good wax does not bring lumps if not used in too great quantities. Adding resin to a soft lumpy wax will render it smooth and pliable. Oil waxes are lighter in color than tallow waxes.

LAWN EXPERIMENT.

An experiment with lawn plats was begun in the summer of 1905, with the active advice and coöperation of the Director The object of this was to test the influence of different fertilizers upon the permanence of white clover and certain grasses and to compare the adaptability of different grasses and mixtures for lawns, golf links, and polo grounds.

A triangular piece of land at the end of the horticultural grounds afforded opportunity for twenty-five plats each fourteen by twenty feet in size, with paths two feet wide between. Partial plats adjoining the diagonal boundary line afforded opportunity for further plats varying in size, and making thirty-three in all.

The plan of the experiment was as follows:

I. *Fertilizer furnishing an acid residue.*—Sulfate of ammonia, acid phosphate, muriate of potash.

Plat 1. Kentucky blue-grass (*Poa pratensis*).
" 2. Rhode Island bent (*Agrostis canina*).
" 3. Redtop (*Agrostis alba*).
" 4. Red fescue (*Festuca rubra*).
" 5. Mixture No. 1: Kentucky blue-grass, Rhode Island bent, redtop, white clover.
" 6. Mixture No. 2: Rhode Island bent, redtop, red fescue.
" 7. Henderson's lawn grass.

II. *Fertilizer furnishing an alkaline residue.*—Basic slag. muriate of potash, nitrate of soda.

Plat 8. Kentucky blue-grass.
" 9. Rhode Island bent.

FIG. [illegible] The Lawn Plats.

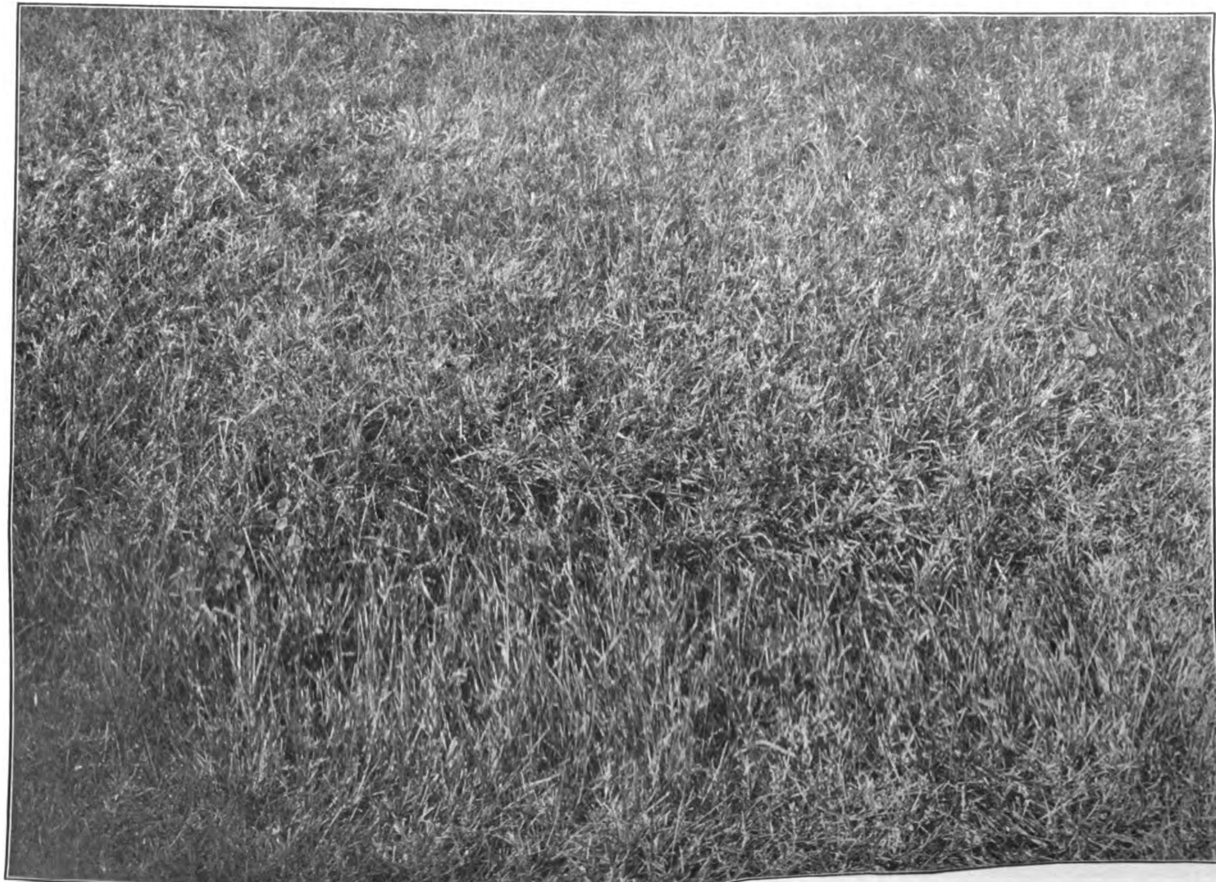

FIG. 2.—Rhode Island Bent.

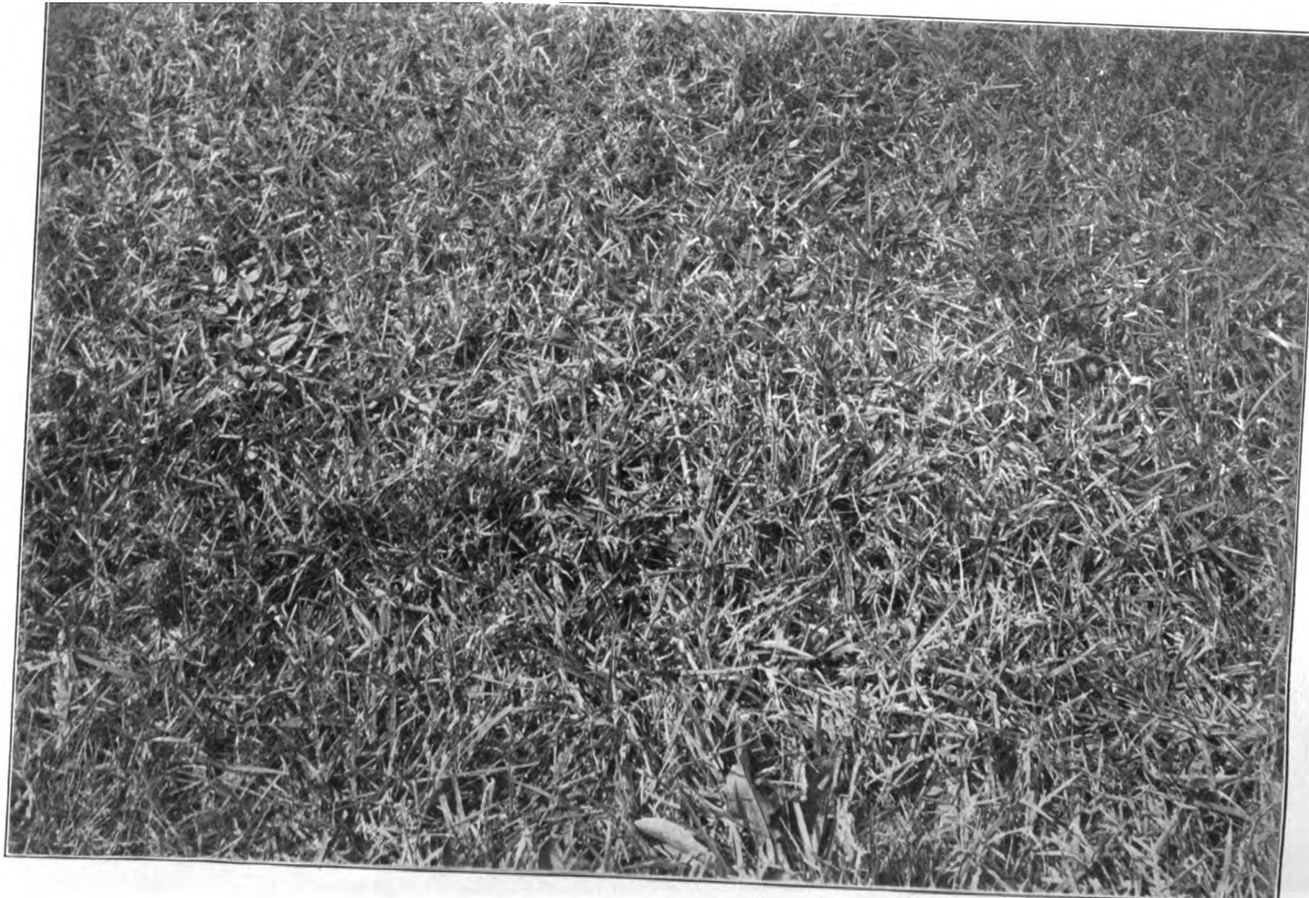

Fig. 8.—Redtop.

Fig. 4.—Red Fescue.

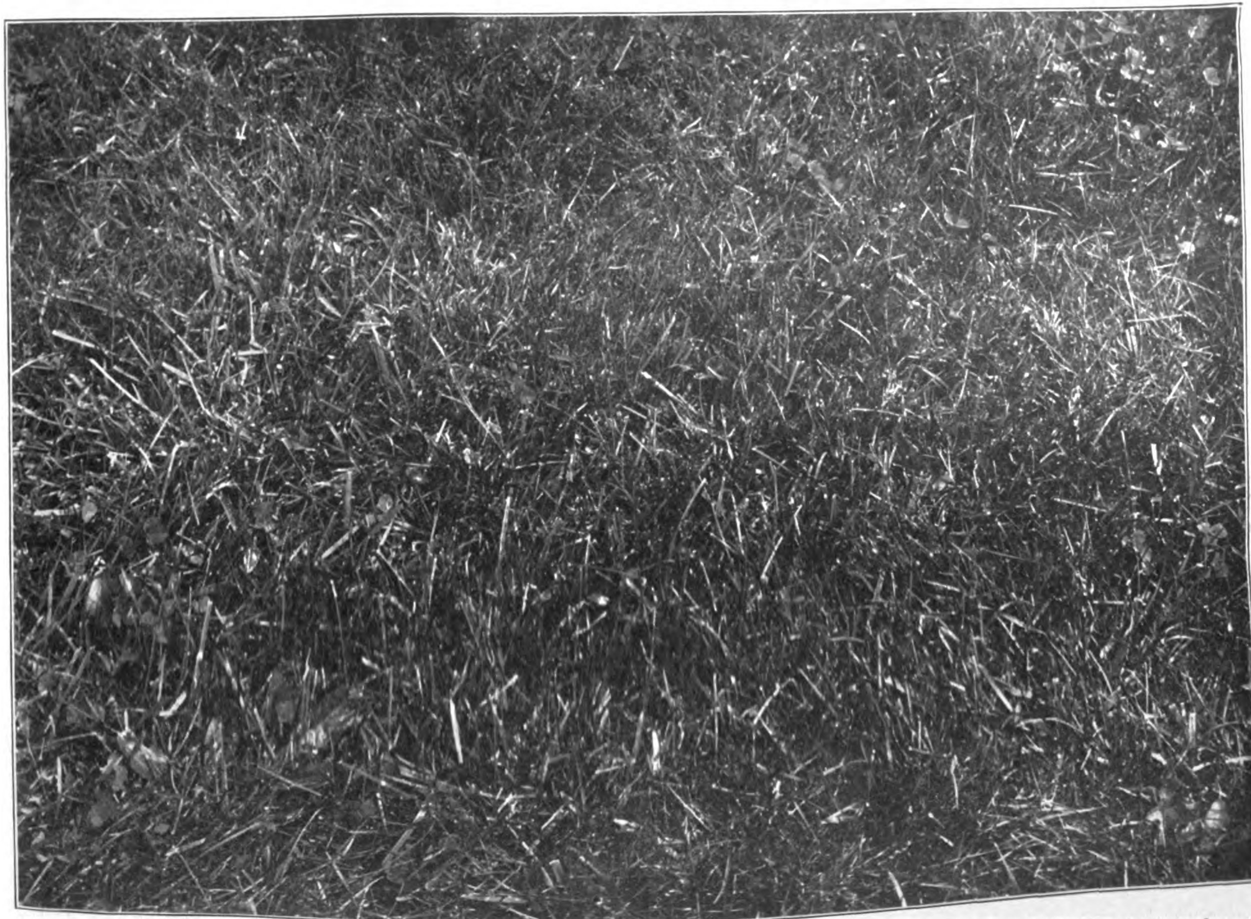

Fig. 5.—Grass Mixture No. 1. Kentucky Blue-grass, Rhode Island Bent, Redtop, and White Clover in equal parts by weight.

FIG. 6.—Henderson's Lawn Grass. White Clover and Perennial Rye Grass the prominent features.

Plat 10. Redtop.
" 11. Red fescue.
" 12. Mixture No. 1: Kentucky blue-grass, Rhode Island bent, redtop, white clover.
" 13. Mixture No. 2: Rhode Island bent, redtop, red fescue.
" 14. Henderson's lawn grass.

III. *Fertilizer furnishing a nearly neutral residue.*—Acid phosphate, muriate of potash, nitrate of soda, ground bone.

Plat 15. Kentucky blue-grass.
" 16. Rhode Island bent.
" 17. Redtop.
" 18. Mixture No. 1: Kentucky blue-grass, Rhode Island bent, redtop, white clover.
" 19. Henderson's lawn grass.

IV. *Fertilizer tests.*—Grass mixture No. 1.

Plat 20. Acid fertilizer (sulfate of ammonia, acid phosphate, muriate of potash), with one-third ration of nitrogen.
" 21. Acid fertilizer, with one-third ration of phosphoric acid.
" 22. Acid fertilizer, with one-half ration of potash.
" 23. Acid fertilizer, with one-half ration of potash and one-third ration of nitrogen.
" 24. Alkaline fertilizer—Nitrogen from dried blood (dried blood, basic slag meal, muriate of potash).
" 25. Acid fertilizer.—Potash from sulfate. (Sulfate of ammonia, acid phosphate, sulfate of potash.)

V. *Additional grasses.*—Partial plats. Neutral fertilizer (acid phosphate, muriate of potash, nitrate of soda, ground bone).

Plat 26. Thorburn lawn-grass.
" 27. Thorburn lawn-restoring mixture.
" 28. Thorburn putting-green mixture.
" 29. Thorburn golf-links mixture.
" 30. Henderson terrace-sod mixture.
" 31. Henderson tough-turf mixture.
" 32. Creeping bent (*Agrostis stolonifera*).
" 33. Canada blue-grass (*Poa compressa*).

The fertilizer ration used in all cases, no matter what the source of the materials, was as follows:

	Per acre.	Per plat.
Actual nitrogen	50 lbs.	5.14 ozs.
Actual phosphoric acid	60 "	6.17 "
Actual potash	150 "	15.42 "

The amount of seed used was six ounces per plat, equivalent to 58.3 pounds per acre. The area of each partial plat was calculated so that the fertilizer and seed were applied at the same rates per acre as in the full sized plats.

Of the seed used, the following kinds were obtained from J. M. Thorburn & Company: Kentucky blue-grass, redtop, red fescue, white clover, creeping bent, Canada blue-grass, Thorburn lawn-grass, Thorburn lawn-restoring grass, Thorburn golf-links mixture, Thorburn putting-green mixture. The remaining kinds, consisting of the following, were obtained from Peter Henderson and Company: Rhode Island bent, Henderson's lawn-grass, Henderson's terrace-sod lawn-grass, Henderson's tough-turf lawn grass.

The land, which had been under the plow for several years previously, was kept well tilled during the early part of the season so as to be in excellent condition for seeding.

The plats were fertilized and seeded on August 11, 1905; the seed being raked in by hand and the ground rolled with a hand roller.

The plats were not mowed during the fall of 1905. Some of them made so much growth that spots were killed out by the grass that remained on them during the winter.

Fertilizer of the same amount and character as that applied at the time of seeding was applied to the surface May 21, 1906.

The following notes explain the character of lawn resulting from the different methods of treatment as observed in the autumn and early summer:*

Kentucky Blue-grass.—This grass did not make a strong start at the

*Later observations modify some of these impressions.

beginning, though apparently germinating well and being thick on the ground. Plat 8 was quite weedy at the south end, where it extended upon an old roadway. A pronounced yellowish tinge was apparent during the autumn, but in spring the appearance was good.

Rhode Island Bent.—This made a very fine, thick growth in the fall; though somewhat unevenly sown. A bluish tinge was apparent. It gave a very fine, velvety turf in the spring, but somewhat spotted from the dead grass which showed through.

Redtop.—This proved to have been unevenly sown, but made a strong growth, giving a good, green appearance in the fall. At the beginning of the summer of 1906 it appeared fairly even, but coarse in texture as compared with Kentucky blue-grass, and especially in comparison with Rhode Island bent.

Red Fescue.—This grass is so fine that the plats appeared bare and thin during the autumn, but the following spring they seemed very good, the color then being dark green. The plats showed a slight admixture with coarser grasses, chiefly velvet grass or meadow soft grass (*Holcus lanatus*).

Mixture No. 1.—Kentucky blue-grass, Rhode Island bent, redtop, white clover. This mixture made an excellent start, producing a lawn quickly. The white clover was very noticeable in autumn. In spring the lawn was very good.

Henderson's Lawn-grass made a very prompt showing, owing to the presence of a coarse, slender, shiny grass which later proved to be perennial rye-grass. The finer grasses were not very thick; this one being most prominent. The following spring these plats appeared coarse and less attractive than most of the others.*

Mixture No. 2—.Rhode Island bent, redtop, red fescue. This mixture started well and produced a good lawn; the grass appearing fine and short in the autumn.

* The final judgment as to the relative merits of all of the mixtures and individual grasses must be delayed for possibly several years.

No noticeable differences could be detected in plats Nos. 20 to 25, which received varying amounts of different fertilizer ingredients.

Thorburn Lawn-grass.—This made a fine start, the grass being thick and vigorous, with good, dark-green color. It made a good, fine turf the following spring.

Thorburn Lawn-restoring Mixture.—This made a strong, vigorous growth in autumn, being tall and thick, with a yellowish-green tinge, but coarse in appearance the following spring.

Thorburn Putting-green Mixture.—This was similar in appearance to the lawn-restoring mixture, but made a good growth.

Thorburn Golf-links Mixture, Henderson's Terrace-sod Mixture, and Henderson's Tough-turf Mixture were all similar in appearance to Henderson lawn-grass, owing to the presence of perennial rye-grass, which, being a strong grower, makes a quick showing.

Creeping Bent.—A fine, short grass with good color, which started well and gave promise of a good turf the following spring.

Canada Blue-grass.—A very fine, short grass which makes the lawn look bare at the beginning, but which produced a nice, even blue lawn early in spring.

A Market-Garden Rotation

This experiment, as explained in the annual report for 1905, is designed to compare stable manure with chemicals in the growing of market-garden crops, a cover-crop being introduced wherever possible in the plat upon which chemicals are used.

The experiment was begun in 1904, the crop that year being corn followed by beans on part of each plat and beans followed by corn on the remainder.

Crimson clover was sown in the plat receiving chemicals, August 19, 1904. A fair amount of this lived through the winter and was allowed to grow until the land was plowed, which was done June 7, 1905.

FIG. 7.—The Market-garden Plats, October 1906. Stable manure used at the left, chemicals at the right.

The stable-manure plat received one cord of stable manure and the other plat 200 pounds of chemicals as in the previous year, this being at the rate of ten cords of manure and one ton of chemicals per acre. In the previous year the nitrate of soda was applied at intervals but for the tomato crop it was thought best to apply the whole amount with the other fertilizer, which would be the common custom in commercial tomato growing.

Dwarf Stone tomatoes were planted upon both plats June 9, 1905. The plants upon the plat receiving fertilizer made a better start and maintained their superiority throughout the season. The yields harvested from the two plats were as follows:

Date.	Plat fertilized with stable-manure.	Plat fertilized with chemicals.
Aug. 29	5 lbs. 4 ozs.	9 lbs. 2 ozs.
" 31	4 " 3 "	7 " 10 "
Sept. 1	11 "	1 " 10 "
" 5	20 " 2 "	29 " 8 "
" 8	20 "	36 " 13 "
" 9	58 "	65 "
" 13	29 "	65 " 4 ozs.
" 16	32 " 10 ozs.	65 " 2 "
" 19	62 "	62 "
" 21	116 " 8 ozs.	159 " 8 ozs.
" 23	179 "	313 "
" 26	133 "	161 "
" 28	53 "	115 "
" 30	50 "	62 " 12 ozs.
Oct. 5	68 "	58 "
" 7	130 "	108 "
" 11	35 "	28 "
Marketable tomatoes	996 lbs. 6 ozs.	1,347 lbs. 5 ozs.

On the date of the last picking, October 11, all tomatoes were removed from both plats and weighed. In addition to those which were ripe and are included in the above list, the following were obtained:

	From stable-manure plat.	From chemical plat.
Green tomatoes	439 lbs.	242 lbs.
Rotten tomatoes	255 "	171 "

It will be seen from the above figures that the plat receiving chemicals produced 350 pounds, 15 ounces, more marketable tomatoes than the one receiving stable manure, an increase of thirty-five per cent. There were 197 pounds more green tomatoes when the plats were cleaned up, October 11, on the one which had received stable manure than on the one which had received chemicals. There were also eighty-four pounds more of rotten tomatoes upon the former plat. While the difference in total yields, including marketable, green, and rotten tomatoes, is not great, being only 69 pounds and 7 ounces greater from chemicals than from manure, the difference in the quantity of marketable tomatoes is decided.

Reference to the weights harvested at different dates will show that a larger proportion of ripe fruit was obtained early in the season from the use of chemicals than from the use of stable manure. A comparison of the first five pickings shows that during this early fruiting period 67½ per cent. more fruit was obtained from the plat treated with chemicals than from the other. These results are in harmony with generally accepted views concerning the influence of nitrate of soda in hastening the maturity of tomatoes.

Rye (one peck) was sown and raked in among the tomatoes on the plat treated with chemicals, on August 2, 1905, the other plat being raked over at the same time and in the same manner. This rye was allowed to grow until the plat was plowed the following spring, at which time it had produced a good growth, furnishing a considerable amount of vegetable matter to turn under.

A RASPBERRY SCORE-CARD.

The necessity of making practical notes upon raspberry seedlings produced from crossing different varieties has led to the adoption of a score-card somewhat similar to the one used for strawberries,

which was shown in the annual report for 1905. This score-card for raspberries has not been used long enough to prove its merits. Further use may suggest some modifications, but at present it appears to be fairly well adapted to the purpose and is shown here for the possible aid of any who may have similar work to do.

RASPBERRY.

Variety. . . . .

SCALE-POINTS 10-Perfect.

Plant.

Vigor	Disease Resistance

Fruit.

Productiveness	Size
Appearance	Quality
Firmness	Cohesion

DESCRIPTION.

Plant.

Habit
Propagation

Fruit.

Form	Color
Flavor	Drupelets
Season	
General Notes	

Date. Observer

STERILIZED SOIL.

The work with sterilized soil was continued in 1905.* The different methods of treatment under test, as in 1904, were as follows:

1, Unsterilized; 2, Sterilized and handled while hot; 3, Sterilized and handled cold; 4, Sterilized and sprinkled lightly with rich, unsterilized soil to introduce soil organisms; 5 Sterilized and treated with nitrate of soda at intervals.

* See annual report for 1905, page 204.

Galvanized iron pots not being available in 1904, large flower-pots were used for the experiment. These were objectionable from the fact that in summer weather in the open air they permit the soil to dry out very rapidly. The soil used was taken from the north garden, and was in only a fair state of fertility. This was sterilized May 18, 1905, and the pots filled according to the plan outlined, four pots being used for each part of the experiment, two being planted with French Breakfast radish and two with Hanson lettuce. The garden soil used to sprinkle upon the four pots treated in this way was also taken from the north garden, May 31.

As the work progressed it was noticed that the unsterilized soil appeared to dry out sooner than the others. Some weeds appeared in this pot, as would be expected. Pots containing sterilized soil which was handled while hot appeared to retain moisture better than any of the others. None of the lettuce thrived well. Nearly all the radishes in one pot of unsterilized soil were eaten off by some small insect, and more seed was planted June 6. Pot No. 2 of the unsterilized soil seemed to be in advance of any of the others with Nos. 1 and 2 of sterilized soil handled hot occupying second place. On June 12 the radishes were thinned to nine in each pot.

The following observations as to maturity were made June 17. Pot No. 2 of unsterilized soil had six radishes mature, 2 half mature, and one small. In sterilized soil sprinkled with garden soil none were yet half mature. In sterilized soil which had been handled cold four radishes were half mature, the remainder being small. In the sterilized soil handled hot five were mature, five two-thirds mature, the remainder half mature. In sterilized soil fertilized with nitrate of soda two were half mature, the remainder small.

The radishes were harvested June 27, and the following weights were obtained:

	Total yield.	Wt. of leaves.	Wt. of roots.
Unsterilized	141.6 grams.*	46.2 grams.	95.4 grams.
Sterilized, handled hot	272.3 "	92.6 "	179.7 "

*Only two plants were obtained from pot No. 1. the second planting also having failed.

	Total yield.	Wt. of leaves.	Wt. of roots.
Sterilized, handled cold	193.25 grams.	68.4 grams.	124.85 grams.
Sterilized, sprinkled with garden soil	219.15 "	77.4 "	141.75 "
Sterilized, with nitrate of soda added	212.2 "	73.7 "	138.5 "

Radishes obtained from the sterilized soil handled hot were not only larger, as the weights show, but were also brighter in appearance, making a better-looking crop. Those from the unsterilized soil were next in appearance, but not as smooth and bright as from the sterilized. Those from the pots sprinkled with garden soil, which are next in order as to weight, were bright, smooth, and symmetrical, being better in form than those from the unsterilized soil. Those from the sterilized soil with nitrate of soda added were also bright, smooth, and symmetrical, and very uniform in size and shape. Those from the sterilized soil handled cold were more uneven and were not equal in appearance to any of the others.

The lettuce in all pots made a very poor growth, probably due to the pots drying out in the hot weather. That grown in the unsterilized soil was somewhat better than in the others. All lettuce was pulled and the pots planted with rutabaga turnips August 31. Worms ate the leaves of these badly, but all were eaten in about the same proportion. They were pulled and weighed late in the fall with the following results:

	No.	Total weight.	Wt. of root.
Unsterilized	11	.21 lbs.	.08 lbs.
Sterilized, handled hot	10	.29 "	.14 "
Sterilized, handled cold	10	.24 "	.14 "
Sterilized, sprinkled with garden soil	10	.18 "	.09 "
Sterilized, with nitrate of soda added	10	.24 "	.11 "

Marguerite carnations were planted July 6 in the pots from which radishes had been harvested. The pots containing unsterilized soil still appeared to be drier than the others, and those containing sterilized soil handled hot still appeared to hold moisture better than the others. The number of carnations picked from the different lots was as follows:

	September 1.	13.	21.	26.	Total.
Unsterilized soil	1	..	..	..	1
Sterilized, handled hot	..	..	..	1	1
Sterilized, handled cold	..	..	1	..	1
Sterilized, sprinkled with garden soil	..	..	..	..	..
Sterilized, with nitrate of soda added	..	1	..	1	2

	October 5.	9.	12.	13.	16.	18.	21.	25.	31.	Total.
Unsterilized soil	..	2	1	..	1	1	..	..	..	5
Sterilized, handled hot	1	1	1	..	..	..	..	1	..	4
Sterilized, handled cold	..	..	..	..	..	..	..	..	..	
Sterilized, sprinkled with garden soil	..	..	1	1	..	..	..	..	..	2
Sterilized, with nitrate of soda added	..	1	..	..	2	..	1	..	1	5

	November 6.	9.	10.	14.	Total.	Total Entire period.
Unsterilized soil	..	..	..	..		6
Sterilized, handled hot	..	..	..	..	..	5
Sterilized, handled cold	..	3	..	1	4	5
Sterilized, sprinkled with garden soil	..	..	..	..	..	2
Sterilized, with nitrate of soda added	1	1	1	..	3	10

The thermometer dropped to 12° above zero and earth froze in some of the pots on the night of Nov. 13, and records were not continued longer.

So far as these tests go, any gain which might be expected to result from the re-introduction of soil organisms into a sterilized soil by sprinkling it with unsterilized soil has not appeared. Handling the sterilized soil while still hot, instead of proving injurious, as has been suggested, appeared to act beneficially.

TENT COVERING FOR VEGETABLES.

This experiment was continued in 1905 with cauliflower alone, that being the vegetable which in previous experiments had shown the greatest gain from the covering. The land inside the tent, which

was 12 x 48 ft. in size, together with the same area outside, was spaded May 27 and cauliflower plants set May 29. The ground outside the tent was very dry, so that the soil was tramped around each plant after it had been set. The plants inside made a much better start and continued to make a better leaf-growth throughout the summer. The ground inside the tent remained moist much longer after rain than that outside.

The following yields were obtained inside the tent:

Date.	Untrimmed.	Trimmed.
July 19	2 lbs. 6 ozs.	1 lb. 8 ozs.
" 26	6 " 6 "	3 " 12 "
" 27	17 " 4 "	11 " 4 "
" 29	14 "	7 " 2 "
Aug. 2	12 " 10 "	7 " 4 "
" 4	39 " 10 "	24 " 8 "
" 11	89 " 8 "	76 "
" 17	238 " 9 "	166 " 7 "
" 23	48 " 9 "	21 " 3 "
" 26	57 " 9 "	26 "
Sept. 5	29 " 3 "	17 " 7 "
" 13	60 "	33 "
" 15	49 " 3 "	21 "
Total	664 lbs. 13 ozs.	416 lbs. 7 ozs.

YIELDS OUTSIDE THE TENT.

Date.	Untrimmed.	Trimmed.
July 19	1 lb. 10 ozs.	12 ozs.
" 27	15 lbs. 10 "	9 lbs. 10 "
Aug. 4	2 "	1 " 4 "
" 11	43 "	30 " 12 "
" 17	194 " 14 "	107 " 13 "
" 23	42 " 9 "	24 " 11 "
" 26	73 " 14 "	36 " 12 "
Sept. 5	34 " 5 "	20 " 10 "
" 13	45 "	19 "
" 15	16 " 12 "	10 " 3 "
Total	469 lbs. 10 ozs.	261 lbs. 7 ozs.

The above figures show the total weight of trimmed cauliflower to have been sixty per cent greater under the tent than outside. The proportionate net weight of trimmed to untrimmed cauliflower was fifty-six per cent. in that grown outside and sixty-four per cent. in that grown inside, which indicates a relatively better development of heads. Whether this increase in yield would be sufficient to warrant the expense of providing shade, each grower would need to determine for himself.

Our experience indicates that it is possible to grow cauliflower under the tent in weather when it is almost impossible to secure it outside.

Young cauliflower plants were set August 7 in the places where mature heads had been harvested, but nearly all of these plants rotted off close to the ground, both under the tent and outside. Waste leaves from the previous crop had been allowed to lie on the ground, which doubtless contributed to this trouble.

The following readings, taken at various times throughout the season, show the comparative air temperatures under the tent and outside, the thermometers being hung about four feet from the ground in each case:

Date.	Time.	Temperature inside.	Temperature outside.
June 16	8:45	90°	82°
" 17	10:30	84°	78°
" 24	11:30	78°	76°
" 24	2:15	85°	84°
" 26	11:30	90°	84°
" 27	10:15	68°	65°
" 27	11:30	82°	73°
July 1	11:00	88°	78°
" 3	9:30	74°	72°
" 5	10:30	77°	74°
" 6	1:30	87°	83°
" 6	5:00	75°	72°
" 8	9:45	85°	82°
" 10	8:45	95°	94°

Date.	Time.	Temperature inside.	Temperature outside.
" 10	11:00	98°	91°
" 10	3:15	92°	89°
" 11	10:00	95°	90°
" 12	8:30	88°	87°
" 14	10:00	88°	82°
" 17	9:30	76°	*77°
" 18	11:15	101°	95°
" 19	1:30	96°	92°
" 20	10:00	93°	87°
" 21	8:30	82°	74°
" 24	11:15	74°	73°
" 25	10:30	90°	84°
" 25	2:30	87°	82°
" 26	8:45	83°	78°
" 27	9:15	88°	83°
" 28	2:15	90°	87°
" 29	9:30	73°	*74°
" 30	8:30	86°	88°
" 31	1:45	78°	76°
Aug. 2	10:30	85°	80°
" 2	4:30	78°	78°
" 3	2:15	88°	84°
" 4	10:00	90°	83°
" 7	3:00	93°	91°
" 8	4:30	81°	79°
"1 1	1:00	91°	86°
Average		85.55°	81.675°

These figures show the average temperature during the day to have been nearly 4° warmer inside the tent than outside. The greatest difference observed at any one reading was that taken at 11:00 A. M. July 1, when the inside temperature was 10° higher than that outside.

*Cloudy.

DIVISION OF ANIMAL HUSBANDRY.

The work of this Division will be prepared for publication and issued in bulletins and the Report of the coming year.

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DIVISION OF CHEMISTRY.

5

REPORT OF THE DIVISION OF CHEMISTRY.

B. L. HARTWELL, ASSOCIATE CHEMIST.

The principal analytical work, aside from the regular inspections of fertilizers and feeding-stuffs, has been in connection with the determination of the ash constituents of plants grown in soil to which different relative amounts of soda and potash had been applied. This work has progressed from time to time during a number of years as successive crops have been obtained, but it was only through the financial assistance of the Bureau of Soils of the U. S. Department of Agriculture that the ash analyses which it seemed desirable to make at the present time were completed. All of the analytical work thus far done in connection with this problem during a number of years has been embodied in an article which follows.

Considerable analytical work has been done for the other divisions of the Station, which will be published by the divisions whenever the time is opportune.

A large number of nitrogen and moisture determinations have been made during the past year on crops which have accumulated from a pot experiment which has been continued for a number of years to ascertain the relative availability of nitrogen in different nitrogenous manures.

Pot and Water-Culture Experiments.

The Bureau of Soils has continued at this Station the trial of its method of ascertaining soil deficiencies by the growth of wheat in small, paraffined wire pots. In order to compare the results obtained by this method with those secured in actual field practice, fifteen soil tests have been begun in different parts of the State upon soils representing a number of different types. Bags of these soils were sent to the Station for pot-cultures, using the same kinds and appli-

cations of manurial substances as in the field. In addition to the cultures in the small, paraffined baskets, a number of the soils are also being tested under similar conditions at the glasshouse in eight-inch Wagner pots. The endeavor will be made to grow crops to maturity in these latter pots, as in the field, whereas in the small pots no attempt is made to grow the wheat more than for about three weeks.

Pot experiments are also in progress to ascertain the amount of nitrogen which can be gathered from the air during the growth of certain legumes in a light soil. Other minor pot experiments are also in progress.

Experiments upon the growth of plants by means of water-culture were continued with the opening of the spring season, an expert having been detailed from the Bureau of Soils to aid in this work. The principal work has been in connection with the question whether or not sodium salts cause an increased growth when there is a limited supply of potash. It has been shown repeatedly in the field that there is an increased growth when sodium salts are added to a limited supply of potash, and the analytical data furnish much circumstantial evidence that the sodium acted physiologically. In order to ascertain by other and more positive means if this increase is due to a direct or an indirect action of the sodium salts, similar experiments by way of sand and water-culture seemed necessary.

In addition to the research work mentioned above, the chemical division has collected and analyzed a large number of samples of commercial fertilizers and feeding-stuffs, the results of which appear in the Station Bulletins.

MISCELLANEOUS ANALYSES.

(Other than those which will be published in connection with special articles).

B. L. HARTWELL, M. STEEL, AND J. P. GRAY.

GROUND LIMESTONE (CARBONATE OF LIME).

From the Mitchell Lime Co., Mitchell, Indiana.

	Per cent.
Calcium oxid	49.26
Magnesium oxid	2.04

This finely ground, unburned limestone is especially adapted to use on sandy soils where the more caustic, slaked, and hydrated lime might exert a temporary injurious action if used in large quantities. If the price is high and the distance of transportation is great it may however be advisable to use the slaked lime in small amounts instead of the carbonate of lime, even on sandy soils.

HYDRATED LIME.

From the Rockland-Rockport Lime Co., Rockland, Maine.

	Per cent.
Calcium oxid	61.37
Magnesium oxid	2.17

This lime is slaked by means of steam and is then bolted, hence it is in an extremely fine condition. When first prepared it is chemically the same as water-slaked lime and both are very efficient on heavy clay and acid muck soils. Air-slaked lime contains a mixture of water-slaked lime and carbonate of lime. Hydrated and water-slaked lime change to carbonate of lime after long exposures to the air.

SLAKED LIME.

	Per cent.
Calcium oxid	68.14

LIME-KILN ASHES.

From Harris Lime-kilns, Lime Rock, R. I.

	Per cent.
Potassium oxid	1.81
Calcium oxid	45.50

The composition of lime-kiln ashes is likely to vary considerably, according to how much the ashes have been exposed to the weather and the consequent amount of water and carbon dioxid contained in them.

MURIATE OF POTASH.

	Per cent. I.	II.	III.
Potassium oxid	60.08	48.67	49.69

No. I. is a *high-grade* muriate of potash bought for special experimental work.

I. "HIGH GRADE" SULFATE OF POTASH.
II. POTASSIUM CARBONATE.

	Per cent. I.	II.
Potassium oxid	51.56	67.65

I. NITRATE OF SODA.
II. SULFATE OF AMMONIA.
III. DRIED BLOOD.

	Per cent. I.	II.	III.
Nitrogen	16.10	20.96	12.11

I. GROUND "ACID FISH."
II. TANKAGE.

	Per cent. I.	II.
Nitrogen	9.42	6.81

The ground "Acid Fish" is the waste menhaden fish from the oil factories which has had a small amount of oil of vitriol (sulfuric acid) sprinkled over it to prevent its decomposition.

I. FINELY GROUND BONE.
II. DISSOLVED BONE.

	Per cent. I.	II.
Nitrogen	2.54	1.74
Phosphoric acid	20.47	14.77

The dissolved bone is finely ground bone which has been treated with considerable oil of vitriol (sulfuric acid) in order to render most of the phosphoric acid soluble in water.

GUANO.

From Coe-Mortimer Co., New York.

I. LOBOS GRADE.
II. CHINCHA GRADE.

	Per cent. I.	Per cent. II.
Nitrogen	3.02	7.76
Phosphoric acid	19.71	9.56
Potassium oxid (acid soluble)	4.08	2.21

Guano, which disappeared from the market for several years, is now to be had again. It is an efficient manure, but as good results can probably be secured with mixtures of acid phosphate, bone meal, the German potash salts, and nitrate of soda; hence, which should be used depends solely upon the relative prices of the guano and a mixture having the same composition.

I. ACID PHOSPHATE.
II. BASIC SLAG MEAL.

	Per cent. I.	Per cent. II.
Phosphoric acid	14.01	17.29

The phosphoric acid of the basic slag meal is not soluble in water, but yet it is highly efficient in plant production, the slag meal being nearly as good as acid phosphate. On very acid soils and with plants injured by acidity it may act even better than acid phosphate. It, like acid phosphate, contains neither nitrogen nor potash.

I. CORN MEAL.
II. MIXED FEED.

	Per cent. I.	Per cent. II.
Water	13.82	.....
Protein	8.50	16.31

CONCERNING THE FUNCTIONS OF SODIUM SALTS.

H. J. WHEELER AND B. L. HARTWELL,

WITH THE ASSISTANCE OF

J. W. KELLOGG AND MATTHEW STEEL.*

The field experiments which have served as a basis for the study of the functions of the sodium salts were begun in the year 1894 and have been continued to date. The original plan was to see at the outset if practical advantage would accrue from the use of sodium salts as manures in the presence of both limited and large supplies of potassium. Having observed in the field great advantage with certain varieties of plants from the use of sodium salts in the presence of small quantities of potassium salts, and even in some cases when large amounts of the latter were employed, it seemed necessary to conduct both pot and water-culture experiments in order to eliminate certain factors which existed in the field work. Special reference is made to the indirect manurial action of sodium salts by virtue of the liberation of essential food elements from the soil itself. The influence of osmotic pressure, the chemical reaction of the medium in which the plants are grown, and other complex features only admit of satisfactory study by the method of water culture. In addition, it appeared desirable to resort to plant analysis in order to determine if more sodium had actually entered the plant, or simply more potassium in consequence of applying sodium salts and also, whether evidence would be afforded that the sodium had been of

*Messrs. Kellogg and Steel, of the Bureau of Soils, U. S. Dept. Agriculture, completed the analytical work, though a part of it had already been done by Mr. Kellogg while still in the employ of the Experiment Station. A large number of analyses had been made previously by Doctor Hartwell.

benefit by increasing the amount of calcium, magnesium, or phosphoric acid at the disposal of the plants.

In preparation for this latter work some plants were saved for analysis in the year 1898, and still more in the year which followed. Likewise in the years 1901 and 1905 samples of a number of varieties of plants were saved from the crops grown in the field experiments. From time to time, as opportunity afforded itself, the analysis of the samples was taken up, but the means at disposal often necessitated the relinquishment of the work for long periods of time. While these conditions still prevailed, application was made to the U. S. Department of Agriculture for aid in carrying forward the work. As a result, the Bureau of Soils arranged for temporary assistance in obtaining analytical data, and it is on account of this assistance that it is possible to present to the public at this time the large volume of results which follow.

It had been shown in earlier times, and had been recently demonstrated by Smets and Schreiber* in Belgium, as well as by others elsewhere, that sodium salts were highly beneficial to certain plants under given conditions of field culture. Nevertheless, it appeared highly desirable to see if there would seem to be reason for assuming, from our own results, whether sodium had acted directly or indirectly, and if probable physiological functions were to be ascribed to it when but small or insufficient amounts of potassium were present.

With the hope of making a clearer presentation of the subject, the analytical data will be presented under three distinct headings. In order, however, that the analyses may be studied in their entirety, if desired, they have all been grouped in an appendix to this article.

Owing to the large amount of work and the expense involved, it was found necessary in many cases to abbreviate the chemical work more than might be deemed advisable. It is believed, however, that valuable and conclusive light is thrown by the results upon a number of points of both scientific and practical value.

*Recherches sur les Engrais Potassiques et Sodiques, Maaseyck, 1896.

The Influence of Sodium Salts Upon the Removal from the Soil of Nitrogen and Phosphoric Acid.

In order to make the discussion of this question better understood, it seems desirable to refer briefly to some of the observations on record which bear upon this question.

Birner and Lucanus* assert that sodium sulfate favors the passage of phosphoric acid into the plant, but that it lowers the per cent. of calcium taken up; also that upon employing potassium chlorid the ash and dry matter of the plants were rendered richer in magnesium and potassium, but poorer in calcium, sulfur, and phosphorus. They further add that sodium chlorid causes calcium, sulfur, and phosphorus to be taken up even more slowly, yet at the same time the percentages of magnesium and potassium were increased in both ash and dry matter.

Griffiths† says that in calcareous soils the sodium carbonate formed therein, in consequence of the application of sodium chlorid, acts as a solvent of phosphoric acid.

Müntz and Girard‡ are of the opinion that if sodium chlorid exerts a solvent action upon soil phosphates and upon the potassium in silicate combinations, this action must be extremely limited.

Pagnoul § conducted some experiments with potatoes, which were followed the second year by oats. He employed white silica as a medium in which to grow his plants, and this, upon analysis, was found to contain the following:

	Per cent.
Calcium carbonate	.00495
Phosphoric acid	.00232
Potassium oxid	.00658
Iron and aluminum oxids	.11000

In all cases like amounts of nitrogen and phosphorus were present

*Landw. Vers. Stat. 8 (1866), p. 140.
†A Treatise on Manures, London (1889), p. 255.
‡Les Engrais III (1891), p. 152.
§Ann. Agron. 20 (1894), p. 467–479.

in the manures. To one series of pots calcium salts were added, to another sodium salts, and to a third potassium salts. In the first series the phosphorus was supplied in solution, in superphosphate of lime, and in the other two cases in sodium and potassium phosphate, respectively. The percentage of phosphoric acid in the potatoes was not determined. Below are given the data in relation to the oats:

	Receiving potassium salts.	Receiving sodium salts.	Receiving calcium salts.
	Grams.	*Grams.*	*Grams.*
Total weights of plants	716.2	508.8	311.7
Relative weights	100	71	43
Constituents per 100 parts of dry matter.			
Potassium oxid	7.001	1.192	0.934
Sodium oxid	0.000	4.585	0.920
Calcium oxid	0.634	0.682	1.956
Phosphoric acid	3.043	1.983	1.300
Nitrogen	4.320	4.620	4.480

Pagnoul points out that the crop increased with the increase in total percentage of alkalis, and he further adds that the increase in the yield was almost exactly in accord with the increase in the percentage of phosphoric acid.

In this instance the influence of the calcium, sodium, and potassium was exerted upon the materials which had been applied in solution to the nearly pure silica, and hence it does not deal with the effect of these substances upon the natural phosphatic constituents of ordinary soils.

Dehérain* has called attention to the fact that in a certain section of France where no after-effect of an acid phosphate was noticeable, subsequent liming apparently rendered the phosphoric acid available to plants. Similarly at this Station a soil greatly benefited by applications of dissolved bone-black appeared not to require it for several years subsequent to liming. Other experiments at this Station show the most striking benefit from liming, in connection

*Traité de Chimie Agricole, Paris (1892), p. 525.

with applications of roasted Redondite.* This beneficial effect is believed to be due to the basic action of the lime in the acid soil. If such is the true explanation it might be expected that sodium carbonate, a highly alkaline compound, would, as has been claimed, act similarly upon certain mineral phosphates, and that it would also exert a solvent and decomposing action upon the humus compounds which have a considerable phosphorus content.

It is well known that the presence of sodium chlorid in certain solutions increases their solvent action upon various chemical compounds; hence, it would not be surprising if, as stated by Peligot,† it should exert such an action upon some of the phosphates. It is probably, therefore, not necessary to its influence, as a solvent of certain kinds of phosphorus compounds, that it be changed into sodium carbonate in the soil by reacting upon carbonate of lime, as suggested by Griffiths.‡

It is often a most difficult matter to decide, solely by the chemical examination of a plant, whether deficiencies or excesses of certain ingredients found therein are really indicative of such deficiencies or excesses in the soil in which it was grown. This is well illustrated by the common experience in determining the percentage of nitrogen in very small and immature plants, grown where nitrogen is deficient, since they are almost invariably found to be richer in nitrogen than larger plants which have been supplied with an abundance of nitrogen in readily assimilable combinations. It is known equally well that certain plants remove far more potassium from the soil than they seem to need, a point that has been abundantly established by the Rothamsted investigations and by chemists in many other countries.§

In the case of phosphoric acid, particularly with the cereals, no such excessive overloading of the plant seems to occur as has been observed in connection with root crops, in their removal of potassium.

*Buls. Nos. 114 and 118, R. I. Agr. Expt. Station.

†Compt. Rend. Acad. Sci. (Paris) (1871), p. 1078.

‡Treatise on Manures, (London) (1899), p. 255.

§Jordan and Jenter, Bul. No. 192, N. Y. Agr. Exp. Station (Geneva), 1900, p. 349, show that pea plants took up in one case ten times as much potash as in another.

Hartwell and Kellogg,* in the analysis of crops grown at the Rhode Island Station, found that the flat turnip exhibited striking increases of phosphoric acid with the increased yields. In the case of oats and certain other varieties of plants grown under the same conditions, the analytical data were often conflicting; or in other words, the analysis of these plants often failed to indicate truly and surely the apparent relative availability of the soil phosphates. It is stated by A. D. Hall† that "The proportion of phosphoric acid and of potash in the ash of any given plant varies with the amount of these substances available in the soil, as measured by the response of the crops to phosphatic or potassic manures, respectively.

"The extent of the variation due to this cause is limited, and is often no greater than the variations due to season, or than the other variations induced by differences in the supply of non-essential ash constituents—soda, lime, etc.

"The fluctuations in the composition of the ash are reduced to a minimum in the case of organs of plants, which, like the grain of cereals, or the tubers of potatoes, are manufactured by the plant from material previously assimilated.

"The composition of the ash of the cereals is less affected by changes in the composition of the soil than is that of the root crops like swedes and mangels.

"The composition of the ash of mangels grown without manure on a particular soil gives a valuable indication of the requirements of the soil for potash manuring. Similarly the phosphoric acid requirements are well indicated by the composition of the ash of unmanured swedes."

It appears from what has been cited that, if the other factors are identical, certain of the root crops may show by the composition of their ash, in agreement with the yields, whether or not a deficiency of phosphoric acid exists, and also what influence upon its availability has been exerted by the application of specific substances.

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*Eighteenth Ann. Rpt., R. I. Agr. Expt. Sta. (1904-05), p. 253.
†Jour. of Agr. Sci. 1 (1905), p. 88.

The general presentation of the foregoing matter has, as previously suggested, seemed to be a necessary prerequisite to an intelligible discussion of certain experimental data secured at this Station. Special reference is made in this connection to the yields and to the analysis of certain crops grown in connection with various amounts of sodium and potassium salts.

The complete details of the plan of this experiment and of the crop yields have already been presented elsewhere.*

The opposite diagram shows the plan of the field and the general scheme for the application of the sodium and potassium salts. The two series of plats indicated as "limed 1902" received no second application. The other two series as shown in the diagram were limed in 1894 when the experiment was begun,† and again in 1896 and 1902.

All of the plats were manured in an identical manner with magnesium sulfate (Epsom salts), and with phosphatic and nitrogenous manures. Nitrate of soda and nitrate of potash were not employed as sources of nitrogen, owing to the fact that they would also have supplied sodium and pôtassium. In 1905 ammonium nitrate was employed for the first time to supply a part of the nitrogen. In the earlier years the nitrogen was introduced entirely in dried blood, bone, or tankage, or in mixtures of two or more of these substances.

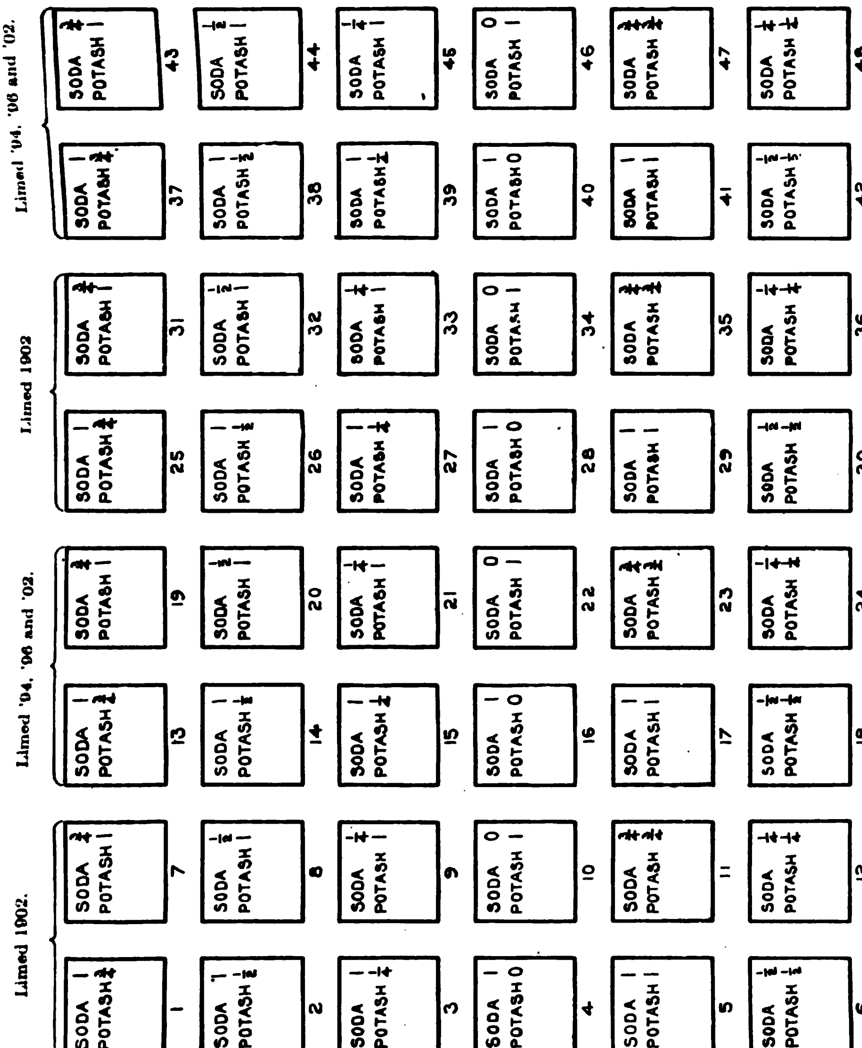
Until 1905 the quantities of potassium carbonate were made such, each year, that the "full ration" would neutralize the same amount of acid as the "full ration" of sodium carbonate. The amounts of muriate of potash and of sodium chlorid (common salt) have been so regulated, when applied, as to furnish the same quantities of potassium and sodium as the respective carbonates.

In the years 1902, 1903, and 1904 the plats were all devoted to grass, and no applications were made to any of them, with the exception of tankage, which was applied to all at a uniform rate.

*Seventh Ann. Rpt. (1894), pp. 168–182; Eighth Ann. Rpt. (1895), pp. 215–231; Ninth Ann. Rpt. (1896), pp. 221–241; Tenth Ann. Rpt. (1897), pp. 226–240; Eleventh Ann. Rpt. (1898), pp. 137–143; Bul. No. 104, Feb., 1905; and Bul. No. 106, May, 1905.

†In Bulletin No. 104, p. 49, mention of the fact that plats 13 to 24 and 37 to 48 were limed again in 1896 was omitted. Also in Bulletin No. 106 the plats said to have been limed twice, including and subsequent to the year 1902, had actually been limed three times.

Plan of Field. Experiment begun in 1894.



Plats 1–24, chlorids, and 25–48, carbonates.

In certain of the years prior to 1902, and also in the year 1905, some of the crops were saved for analysis with the hope that the analytical data might throw some light upon the probable action of the sodium salts. It now remains to consider these results and to discuss their probable significance.

Results with Golden Millet in 1898.

In 1898 each of the forty-eight plats received the following applications:

Pounds per acre.	
1,020	dried blood.
600	dissolved bone-black.
480	floats.
420	magnesium sulfate (Epsom salts).

The full rations of the respective potassium and sodium salts were as follows:

Pounds per acre.	
360.0	potassium carbonate.
247.8	sodium carbonate.
405.0	muriate of potash (manure salt).
278.4	sodium chlorid (common salt, coarse-fine).

All of the materials enumerated above were spread upon the surface after plowing, and were then thoroughly harrowed into the soil.* Below are given the percentages of phosphoric acid in the golden millet from plats Nos. 36 and 27:

Plat No.		Yield of golden millet, green.	Phosphoric acid in dry matter.
		Pounds.	*Per cent.*
36	Carbonates, unlimed, ½ soda, ½ potash..	132.1	.63
27	" " 1 soda, ½ potash..	102.1	.79

In this instance the smaller weight of crop was accompanied by the greater percentage of phosphoric acid and the greater application of sodium carbonate. The smaller yield where the larger amount

*For full details of the yields see Eleventh Ann. Rpt., R. I. Agr. Expt. Sta. (1898), p. 141.

of sodium carbonate was employed may have been due to its lessening the acidity of the soil and thus producing an unfavorable condition for the growth of the millet. The ground for this view is the fact that in twenty-four comparisons upon limed and unlimed acid soil made in the year 1899 the yield of golden millet was found in every case to have been reduced by liming.*

Results with Radish, Flat Turnip, Mangel-Wurzel, Carrot, and Chicory, in 1899.

In 1899 all of the forty-eight plats were manured at equal rates with the following materials:

Pounds per acre.	
1,020	dried blood.
600	dissolved bone-black.
480	floats (finely ground phosphate rock).
420	magnesium sulfate (Epsom salts).

The full rations of the potassium and sodium salts were as follows:

Pounds per acre.	
300.0	potassium carbonate.
331.8	muriate of potash (manure salt).
202.2	sodium carbonate.
231.6	sodium chlorid (common salt, coarse-fine).

The scheme of application of the manures was the same as in 1898. The analyses of the crops show the results with a quarter ration each of the potassium and sodium salts, in contrast with those secured with a quarter ration of potassium salt supplemented with a full ration of sodium salt. These comparisons are made in limed and unlimed series with both carbonates and chlorids; likewise the data show the results under the same conditions with half rations of each salt used together, contrasted with a half ration of potassium salt supplemented by a full ration of sodium salt.

Below are shown the yields of certain varieties of plants, together

*Bul. 104, R. I. Agr. Expt. Sta., Feb., 1905, p. 87.

with the percentages of phosphoric acid and nitrogen actually contained in the dry matter:

Radish, White Strasburg, Roots, 1899.

Plat No.	Special Manures Applied.	Yields,* green, pounds.	Per cent. in dry matter.	
			Phosphoric acid, P_2O_5.	Nitrogen.
12	Chlorids, unlimed; ¼ soda, ¼ potash	547	1.02	3.42
3	Chlorids, unlimed; 1 soda, ¼ potash	709	1.13	3.68
24	Chlorids, limed; ¼ soda, ¼ potash	432	0.89	3.53
15	Chlorids, limed; 1 soda, ¼ potash	685	0.98	3.54
36	Carbonates, unlimed; ¼ soda, ¼ potash	547	0.99	3.33
27	Carbonates, unlimed; 1 soda, ¼ potash	722	1.13	3.74
48	Carbonates, limed; ¼ soda, ¼ potash	432	0.96	3.77
39	Carbonates, limed; 1 soda, ¼ potash	540	1.08	3.60
6	Chlorids, unlimed; ½ soda, ½ potash	797	0.98	3.19
2	Chlorids, unlimed; 1 soda, ½ potash	834	1.02	3.31
18	Chlorids, limed; ½ soda, ½ potash	662	0.84	3.74
14	Chlorids, limed; 1 soda, ½ potash	766	0.90	3.71
30	Carbonates, unlimed; ½ soda, ½ potash	776	1.05	3.47
26	Carbonates, unlimed; 1 soda, ½ potash	817	1.13	3.80
42	Carbonates, limed; ½ soda, ½ potash	621	1.05	3.59
38	Carbonates, limed; 1 soda, ½ potash	662	1.10	3.85

*Yields per one-sixtieth acre.

It will be observed, in the case of the radish, that in every one of the four instances where comparisons are possible there was a smaller percentage of phosphoric acid in the dry matter of the root where only a quarter ration of each salt was used than where the extra three-quarter ration of the sodium salt was added. Similarly in every one of the four cases where a combination of a half ration each

of sodium and of potassium salt was employed the percentage of phosphoric acid in the dry matter was less than where an extra half ration of the sodium salt was present. Comparing the results with carbonates and chlorids, it is seen that the percentages of phosphoric acid were identical in one case, in a second the chlorid gave a higher percentage, and in the other six instances the percentages were lower in the case of the chlorids than where the carbonates were used.

Liming lowered the percentage of phosphoric acid in the crop in all but one of the eight cases, and in that instance the results were identical. Notwithstanding that liming seems to aid in placing at the disposal of plants the phosphoric acid which is present in the soil in certain combinations with iron, it is well understood that the presence of large amounts of carbonate of lime in the soil tends to bring about a reversion or fixation of the phosphoric acid applied in superphosphates. This latter effect, and the fact that the slaked lime was applied five and three years before, in consequence of which its action upon the phosphorus compounds of the soil had practically ceased by virtue of its changed chemical character, account readily for the lesser percentage of phosphoric acid in the radish roots from the limed plats.

The increase in the percentage of phosphoric acid in consequence of the employment of the carbonates, in contrast to the result with the chlorids, may have been due to the solvent action of the carbonates either upon iron, and aluminum phosphates, or upon the phosphorus of the humus compounds.

In view of the fact that increases in the amounts of sodium salts have been shown by these results to unquestionably increase the amount of phosphorus in the plants, the important question arises whether the extra phosphorus was needed in connection with the physiological processes of the plant, or if it was merely an unnecessary surplus. If the extra phosphorus were necessary to the physiological processes, it would hardly be expected that equally large crops would be produced with smaller percentages. Viewed in this light, the results furnish further interesting evidence. For example, in three

instances the percentages of phosphoric acid in the dry matter were 1.13, the maximum amount, and the corresponding yields of radishes were 709, 722, and 817 pounds; again, there was a yield of 797 pounds with a phosphoric acid percentage of .98. one of 834 pounds with but 1.02 per cent. of phosphoric acid, one of 766 pounds with a phosphoric acid content of but .90 per cent. and one of 776 pounds with a percentage of 1.05 of phosphoric acid. In so far, therefore, as these results afford a basis for conclusions, there seems to be considerable evidence that the extra phosphoric acid which the plants in some cases appropriated may not have been actually required. If this is the correct interpretation to place upon the evidence, it would appear as if the increased yields of radishes were very likely due, not to the phosphoric acid, but to some direct beneficial influence of the sodium salt. A yield of 709 pounds in this case was equivalent to 42,540 pounds per acre, showing that the crops were of a normal size.

At this point it will be well to consider certain results with the English, or flat turnip.

Turnip, Flat, Roots, 1899.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter. Phosphoric acid.	Per cent. in dry matter. Nitrogen.
24	Chlorids, limed; ½ soda, ½ potash	214	0.98	*
15	Chlorids, limed; 1 soda, ½ potash	293	1.26	*
36	Carbonates, unlimed; ½ soda, ½ potash	149	1.00	4.19
27	Carbonates, unlimed; 1 soda, ½ potash	212	0.89	3.92

*Not determined.

In this instance the data are too few to throw any light upon the relative action of the carbonates and chlorids upon the amount of phosphorus removed by the plants. The same is also true concerning

the action of lime. The higher percentage of nitrogen in this instance coincided with the higher percentage of phosphoric acid and the smaller yield.

It is significant to observe that in both instances there were considerably greater yields where the extra amount of sodium salt was added than where only a quarter ration each of sodium and potassium salts was applied. Nevertheless in one instance the percentage of phosphoric acid increased with the increase in the crop, and in the other case the percentage was .11 less in the larger crop than in the smaller. Such evidence as is afforded is therefore to the effect that the extra sodium salt was positively helpful in increasing the crops, and there is no positive evidence that this increase was due to indirect action in liberating phosphoric acid.

Below are given a few data secured with the Norbiton giant beet (Mangel-wurzel) in 1899.

Beet, Norbiton Giant, Roots, 1899..

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
24	Chlorids, limed; ¼ soda, ¼ potash	421	0.24	1.63
15	Chlorids, limed; 1 soda, ¼ potash	682	0.32	1.75
48	Carbonates, limed; ¼ soda, ¼ potash	299	0.37	2.23
39	Carbonates, limed; 1 soda, ¼ potash	601	0.39	2.20

In both of the foregoing instances the percentages of phosphoric acid and of nitrogen in the crop were greater where the carbonates were employed than where the chlorids were used. In respect to the phosphoric acid the results are in agreement with those obtained with the radish in the same year.

In the chlorid series the nitrogen and phosphoric acid were both

increased by the extra sodium, but in the carbonate series no such relationship existed.

These results also agree with those secured in connection with the radish in showing an increase in the phosphoric acid percentage in the dry matter when the quarter ration each of the two salts was supplemented by a three-quarter ration of the respective sodium salt. At first thought one might be led to conclude that the remarkable benefit from the sodium salt was attributable to its having rendered more phosphoric acid assimilable, yet in view of the fact that the crop of 299 pounds contained a percentage of 0.37 of phosphoric acid and the one of 421 pounds contained a percentage of but 0.24 of phosphoric acid, this does not seem probable. Furthermore, in view of the fact that the crop of 601 pounds showed a percentage of 0.39 of phosphoric acid as compared with 0.32 in the instance of the crop of 682 pounds, it is difficult to accept such an explanation. These data indicate, rather, that the sodium salt was of some other benefit to the plant.

So far as concerns the nitrogen, the percentage was greater in one case and smaller in the other, when the larger crops were secured.

Results with Carrots in 1899.

The following data were secured in connection with the carrot in 1899:

Carrot, Roots, 1899.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
24	Chlorids, limed; ¼ soda, ¼ potash................	343	1.03	2.58
15	Chlorids, limed; 1 soda, ¼ potash................	483	1.20	2.73
48	Carbonates, limed; ¼ soda, ¼ potash.............	373	1.07	3.02
39	Carbonates, limed; 1 soda, ¼ potash.............	483	1.09	2.93

It will be observed that the use of an extra amount of sodium salt was accompanied by increased crops in both instances. The results with the carrot are conflicting in so far as concerns the respective influence of the carbonates and chlorids upon the phosphoric acid content of the roots, but in the case of the nitrogen the percentage was higher in both instances when the carbonates were used than when the corresponding chlorids were employed.

In both cases the results agree in showing a greater percentage of phosphoric acid in the dry matter when an extra three-quarter ration of the sodium salt was added.

In view of the difference in yield of 110 pounds in the case of the crops from plats Nos. 39 and 48 when the difference in the percentage of phosphoric acid in the dry matter amounted to but 0.02, it does not seem justifiable to conclude that the soda had increased the crop by virtue of aiding in rendering the phosphoric acid available. Furthermore, if the percentage of 1.20 of phosphoric acid were necessary to the production of the 483 pounds of crop in the case of plat No. 15, it would not have been possible to have produced the crop of 483 pounds in the case of plat No. 39 with only 1.09 per cent. of phosphoric acid present in the dry matter of the plants. To be sure, the chlorin in the one case and the carbon dioxid in the other might be mentioned as other factors which would militate against such a line of argument, but nothing of this kind can be advanced as an objection to the argument employed in connection with plats Nos. 39 and 48.

Where the extra amount of sodium salt was applied and both the crop yields and the percentages of phosphoric acid were increased, the nitrogen percentages in the two cases were contradictory.

Results with Chicory Roots.

Below are given certain results obtained with chicory roots in 1899:

Chicory, Roots, 1899.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter. Phosphoric acid.	Per cent. in dry matter. Nitrogen.
24	Chlorids, limed; ¼ soda, ¼ potash................	200	0.49	*
15	Chlorids, limed; 1 soda, ¼ potash................	189	0.48	*
48	Carbonates, limed; ¼ soda, ¼ potash.............	234	0.56	*
39	Carbonates, limed; 1 soda, ¼ potash.............	205	0.59	*

*Not determined.

The chicory affords a striking contrast to the radish, turnip, beet, and carrot on account of the yields having been less where the extra three-quarter ration of sodium salt was used than where only a quarter ration each of the sodium and potassium salts was employed.

The results are in full agreement with those with the radish and beet in showing higher percentages of phosphoric acid when the carbonates were used than when the chlorids were employed.

The differences in the phosphoric acid percentages in the two cases, as influenced by the extra applications of sodium, are not only slight, but also contradictory.

Results with Several Varieties of Plants in 1901.

In 1900 Indian corn was grown upon all of the plats, but no attempt was made to save any of the material for analysis.

All of the forty-eight plats were manured that season at the same rates and with the same kinds of manures as in the previous year (see p. 195), excepting that the full rations of the sodium and potassium salts were as follows:

Pounds per acre.
280.8 muriate of potash (manure salt).
240.0 potassium carbonate.
182.4 sodium chlorid (common salt).
163.2 sodium carbonate (soda ash).

The various plats received the same rations and fractions of rations of the respective salts as in previous years.

In view of the fact that certain analytical data had already shown in the case of the crops of 1899, that the sodium had probably facilitated the taking up of phosphoric acid and possibly of magnesia, it was decided to increase the quantities of phosphatic and magnesian manures applied to all of the plats. In consequence, the quantities of manures used in 1901 were made as follows:

Pounds per acre.
1,296 acid phosphate.
480 floats.
600 magnesium sulfate.
1,020 dried blood.

Below are given the full rations of the respective sodium and potassium salts which were employed:

Pounds per acre.
241.2 muriate of potash (manure salt).
210.0 potassium carbonate.
157.8 sodium chlorid (common salt).
142.2 sodium carbonate (soda ash).

The full rations and fractions of rations of the respective salts were applied to the same plats as in the preceding years.

Below are given the results secured with several of the varieties of plants which were grown upon the plats in 1901.

Radish, White Strasburg, Roots, 1901.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
22	Chlorids, limed; 0 soda, 1 potash	248	1.03	*
20	Chlorids, limed; ½ soda, 1 potash	261	1.09	*
19	Chlorids, limed; ¾ soda, 1 potash	243	1.06	*
34	Carbonates, unlimed; 0 soda, 1 potash	288	1.09	*
32	Carbonates, unlimed; ½ soda, 1 potash	291	1.15	*
31	Carbonates, unlimed; ¾ soda, 1 potash	279	1.12	*
46	Carbonates, limed; 0 soda, 1 potash	228	0.92	*
44	Carbonates, limed; ½ soda, 1 potash	252	1.00	*
43	Carbonates, limed; ¾ soda, 1 potash	243	1.09	*
12	Chlorids, unlimed; ¼ soda, ¼ potash	234	1.08	3.54
3	Chlorids, unlimed; 1 soda, ¼ potash	216	1.08	3.20

*Not determined.

Comparing the results of the examination of the crops from plats Nos. 19, 20, and 22 with those of the crops of plats Nos. 43, 44, and 46, it will be seen that with one unimportant exception a greater percentage of phosphoric acid was not found where the carbonates were employed than where the chlorids had been used. In this respect the results are different from most of those secured with the radish in 1899. This may readily have been due, however, to the larger amount of superphosphate applied in 1901, and to the lesser opportunity for any phosphoric acid to come into play which might have been rendered available by the action of the carbonates either upon iron phosphate or the phosphorus of the humus compounds.

The percentages of phosphoric acid in the crop were in all three instances smaller where the full rations of the potassium salts were used than where the same were supplemented by fractional rations of the sodium salts. Nevertheless, in only one of the three cases was the percentage greater where a three-quarter ration of sodium

salt was used than where but a half ration was added. In none of the cases were there more than incidental differences in yields, and certain of these were in opposite directions from those of the phosphoric acid percentages, so that no positive relationship between the yields, and the percentages of phosphoric acid is exhibited.

In the single comparison of the result when the crop was grown with a quarter ration of each salt with that where an extra three-quarter ration of the sodium salt was added, the percentages of phosphoric acid were identical and the yield was slightly less in the latter instance. In this respect the result differs greatly from those obtained in 1899, when marked increases in yield resulted from the use of the extra sodium salt. The analyses of most of the foregoing crops were made primarily to throw light upon another problem, which will be considered later.

Chicory, Roots, 1901.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter. Phosphoric acid.	Per cent. in dry matter. Nitrogen.
22	Chlorids, limed; 0 soda, 1 potash	243	0.43	*
20	Chlorids, limed; ½ soda, 1 potash	243	0.42	*
19	Chlorids, limed; ¾ soda, 1 potash	243	0.44	*
34	Carbonates, unlimed; 0 soda, 1 potash	162	0.39	0.95
32	Carbonates, unlimed; ½ soda, 1 potash	180	0.41	0.95
31	Carbonates, unlimed; ¾ soda, 1 potash	194	0.40	0.96
24	Chlorids, limed; ¼ soda, ¼ potash	194	0.43	1.03
15	Chlorids, limed; 1 soda, ¼ potash	225	0.53	1.12
48	Carbonates, limed; ¼ soda, ¼ potash	131	0.49	1.14
39	Carbonates, limed; 1 soda, ¼ potash	117	0.48	1.19
	Chicory, Tops, 1901.			
48	Carbonates, limed; ¼ soda, ¼ potash	*	0.51	*
39	Carbonates, limed; 1 soda, ¼ potash	*	0.56	*

*Not determined.

In the series embracing plats Nos. 19, 20, and 21, where the full ration of potassium salt was used, the further addition of sodium salt was not accompanied by an increased yield. In the next series (plats No. 31, 32, and 34) there was a regular increase of crop accompanying each increase in the application of sodium salt.

It will be seen that in the two limed series the yields when only a quarter ration of each salt was used were much less than when a full ration of the corresponding potassium salt was employed. In the instance of the crops from plats Nos. 39 and 48 the use of the additional three-quarter ration of the sodium salt did not increase the yield, though an apparent increase resulted in the limed chlorid series under the same conditions.

There was a lack of positive evidence on the part of the roots that the presence of extra amounts of sodium salts had increased the percentages of phosphoric acid in the plants. Only a mere suggestion to this effect was obtained in the single instance where the tops were examined, in which case there was a slightly greater percentage of phosphoric acid in those grown with the extra amount of the sodium salt.

There is also a suggestion that liming may have raised the percentages of nitrogen in the crop but even this is uncertain in view of the fact that other conditions were variable in the limed and unlimed plats.

Carrot Roots, 1901.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter. Phosphoric acid.	Nitrogen.
24	Chlorids, limed; ¼ soda, ¼ potash................	315	0.93	2.37
15	Chlorids, limed; 1 soda, ¼ potash................	313	0.95	1.98
48	Carbonates, limed; ¼ soda, ¼ potash.............	315	0.77	2.09
39	Carbonates, limed; 1 soda, ¼ potash.............	306	1.04	2.49
	Carrot, Tops, 1901.			
48	Carbonates, limed; ¼ soda, ¼ potash.............	*	0.70	2.87
39	Carbonates, limed; 1 soda, ¼ potash.............	*	0.80	3.08

*Not determined.

It will be seen that the percentage of phosphoric acid was greater in only one of the two instances when the carbonates were employed than when the chlorids were used.

In neither case was the crop greater when an extra three-quarter ration of the sodium salt was used than when only a quarter ration each of the potassium and sodium salt was employed.

In all three instances the percentages of phosphoric acid were greater in the case of the corps grown with the aid of additional sodium salts. It will be seen, therefore, that increased percentages of phosphoric acid resulted in the crop in the case of the carrot tops and roots without an accompanying gain in the yield of roots; in which respect the results differ from those of the year 1899, when smaller amounts of phosphates were used. It is also of interest to note that the percentages of phosphoric acid were also rather less in 1901 than they were in 1899. It is recognized that the climatic differences of the two seasons might alone account for considerable variation in the percentages of phosphoric acid; yet the fact that the increased percentages in 1901 accompanied the use of larger amounts of the

sodium salts without an accompanying gain in crop still further strengthens the belief that the increased yields in 1899, resulting from the use of additional sodium salts, were probably not in consequence of the larger amount of phosphoric acid which the crop had been able to take up.

In the case of the roots the percentage of nitrogen was in one case less and in one case greater when an additional amount of sodium salt was employed, and the difference in the per cent. of nitrogen in the tops is too small to have special significance.

Results with Several Varieties of Crops in 1905.

The plats in this experimental field were devoted to grass in 1902, 1903, and 1904. In each of those years tankage was applied to all of the plats at the uniform rate of 1,200 pounds per acre. Before seeding in the spring of 1902 all of the forty-eight plats were limed at the rate of one ton per acre. It may be mentioned that in 1894 and 1896 plats 13 to 24, inclusive, and 37 to 48, inclusive, had already been limed, but that no lime had been applied to any of the other plats prior to 1902.

In 1905 the plats were plowed, and all were manured uniformly as follows:

Pounds per acre.	
1,500	dissolved bone.
1,000	dried blood.
420	magnesium sulfate.

In this season, for the first time, the idea of using amounts of sodium carbonate for the full ration which should neutralize the same amount of acid as the full ration of potassium carbonate was abandoned. This was for the reason that it was desired to make applications of potassium which would be so great that no additional amount of potassium salts would result in benefit, and it was feared that the use of the larger amounts of chlorids corresponding to the full ration

of potassium carbonate and a full ration of the sodium carbonate might otherwise prove poisonous to the crop.

The full rations of the sodium and potassium salts in 1905 were therefore made as follows:

Pounds per acre.

402.8 muriate of potash (high grade manure salt).
354.9 potassium carbonate.
200.0 sodium chlorid (common salt).
185.0 sodium carbonate (soda ash).

In addition to the usual manures, which were harrowed into the soil, an application of ammonium nitrate at the rate of 72 pounds per acre was made broadcast to all of the plats just prior to the appearance of the young plants. The object in using ammonium nitrate was to have some immediately assimilable nitrate present at the outset, in order that there might be no delay in the growth in consequence of any possible delay in the nitrification of the dried blood.

Half of each plat was devoted to flat turnips and the other half to Strasburg (white) radish.

The yields and the analytical data concerning the crops upon certain of the plats are given below. The yields are calculated to the basis of one-sixtieth of an acre, in agreement with all of the yields which have preceded.

Radish, White Strasburg, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
12	Chlorids, limed once; ¼ soda, ¼ potash...........	398	1.07	3.84
3	Chlorids, limed once; 1 soda, ¼ potash...........	456	1.10	3.50
24	Chlorids, limed thrice; ¼ soda, ¼ potash..........	324	0.98	4.03
15	Chlorids, limed thrice; 1 soda, ¼ potash..........	438	1.08	4.11
36	Carbonates, limed once; ¼ soda, ¼ potash.........	372	1.15	3.76
27	Carbonates, limed once; 1 soda, ¼ potash.........	400	1.26	4.10
48	Carbonates, limed thrice; ¼ soda, ¼ potash........	375	1.03	3.87
39	Carbonates, limed thrice; 1 soda, ¼ potash........	398	1.16	3.87
11	Chlorids, limed once; ¾ soda, ¾ potash...........	557	1.03	3.65
1	Chlorids, limed once; 1 soda, ¾ potash...........	550	0.97	3.47
23	Chlorids, limed thrice; ¾ soda, ¾ potash..........	498	1.00	3.76
13	Chlorids, limed thrice; 1 soda, ¾ potash..........	547	1.05	3.88
35	Carbonates, limed once; ¾ soda, ¾ potash.........	553	1.11	3.65
25	Carbonates, limed once; 1 soda, ¾ potash.........	556	1.16	3.77
47	Carbonates, limed thrice; ¾ soda, ¾ potash,.......	514	1.12	3.82
37	Carbonates, limed thrice; 1 soda, ¾ potash........	555	1.01	3.66

With the exception of a lower percentage of phosphoric acid in the crop from plat No. 37, as compared with the percentage in the case of the crop from plat No. 13, it will be seen that in all of the eight cases where comparisons are permissible the use of sodium carbonate and of potassium carbonate was followed by higher percentages of phosphoric acid than when the corresponding chlorids were employed. In this respect the results support the observations made in 1899. It is of interest to note that the crops were in three cases larger where the chlorids were employed than with the corresponding carbonates, even notwithstanding the greater percentages

of phosphoric acid in the crops produced with the carbonates. This difference in yields appears to have been due, probably, to the fact that the radish often thrives better upon a somewhat acid soil than upon one which has been rendered neutral or alkaline. At all events, an indication is afforded that in these particular instances the amount of phosphoric acid taken up by the plant can not be considered as *the factor* in determining the size of the crop.

An examination of the results where a quarter ration each of potassium and sodium salts was applied reveals the fact that the crops were smaller in every case than where an extra three-quarter ration of the sodium salt was added; and, furthermore, the percentages of phosphoric acid in the crops increased in each instance upon the addition of the extra sodium salt. Where a three-quarter ration of each salt was supplemented by an extra quarter ration of the sodium salt the yields were materially greater in only two of the four cases, and in but one of these instances was the percentage of phosphoric acid in the crop greater than where a smaller amount of the sodium salt had been used. In fact, a three-quarter ration of the sodium salt gave such a large supply that the addition of an extra quarter ration could not be expected to exert the same effect as where the initial amount of the sodium salt was less. Another factor which would also be expected to lessen the effect of the extra amount of the sodium salt was the presence of a three-quarter ration of potassium salt.

In addition to the evidence already presented above, to the effect that the percentage of phosphoric acid in the crop was not *the factor* governing the yield under the conditions of this experiment, it will be observed that in no instance where the yields amounted to over 500 pounds was the percentage of phosphoric acid as great as in the instance of the crop upon plat No. 27, where the yield was only 400 pounds. It will be seen also that in the case of plat No. 36, with a yield of but 372 pounds, the per cent. of phosphoric acid in the crop was larger than in any instance but one, where the crop exceeded 500 pounds. This view that the per cent. of phosphoric acid in the

plant was not the important factor influencing the yield is even more strongly impressed when one observes the commanding influence upon crop production exerted by the extra quantities of potassium salts, as shown by the yields given in the lower as compared with the upper part of the preceding table. If sodium can replace some of the potassium in certain functions, the reason for its benefit becomes more obvious.

It will be observed that in five of the eight cases an increase in the percentage of nitrogen accompanied the increased yields and the use of additional sodium salts, which would give some slight ground for accepting in this case the belief held at Rothamsted and at Halle that sodium is helpful by virtue of acting as a ready carrier of nitrogen to the plant. Yet when one observes that some of the highest percentages of nitrogen accompany certain low yields, the ground for such a conclusion is somewhat weakened.

Below are given the results where the effect of a full ration of potassium salt is compared with that of the same ration supplemented by a half ration of sodium salt.

Radish, White Strasburg, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Phosphoric acid.	Per cent. in dry matter. Nitrogen.
10	Chlorids, limed once; 0 soda, 1 potash	522	1.08	3.51
8	Chlorids, limed once; ½ soda, 1 potash	542	1.06	3.52
5	Chlorids, limed once; 1 soda, 1 potash	574	1.02	3.46
22	Chlorids, limed thrice; 0 soda, 1 potash	522	1.02	3.85
20	Chlorids, limed thrice; ½ soda, 1 potash	553	1.02	3.94
34	Carbonates, limed once; 0 soda, 1 potash	548	1.17	3.60
32	Carbonates, limed once; ½ soda, 1 potash	555	1.19	3.69
46	Carbonates, limed thrice; 0 soda, 1 potash	508	1.06	3.77
41	Carbonates, limed thrice; 1 soda, 1 potash	532	1.09	3.49

It is obvious, from a glance at the yields immediately preceding these, that a three-quarter ration of potassium salt was all that the plants apparently needed in the presence of a three-quarter ration of sodium salt. In all of the four cases in this instance greater yields were obtained where the full ration of potassium salt was supplemented by a half or full ration of sodium salt than where the former alone was employed. Though these results may have been merely accidental, they appear indicative of possible benefit from the sodium salt in the presence of what would seem to have been a sufficient amount of potassium salt. That the increased yields in this particular instance were due to a greater assimilation of phosphoric acid in consequence of the presence of the sodium salts seems doubtful and is not well supported by the relative percentages of the phosphoric acid in the crop. What has been said of the phosphoric acid in this particular appears to be equally applicable to the nitrogen.

These results bear out many previous observations to the effect that the use of the carbonates was accompanied by more phosphoric acid in the dry matter than the use of the chlorids.

Results with the English, or Flat, Turnip, 1905.

Below are given the crop yields and the analytical data in connection with certain of the experimental plats, which were obtained with flat, or English, turnips in 1905.

English or Flat, Turnip, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Phosphoric acid.	Per cent. in dry matter. Nitrogen.
12	Chlorids, limed once; ¼ soda, ¼ potash	240	1.32	3.01
3	Chlorids, limed once; 1 soda, ¼ potash	373	1.39	2.90
24	Chlorids, limed thrice; ¼ soda, ¼ potash	192	1.29	3.13
15	Chlorids, limed thrice; 1 soda, ¼ potash	294	1.35	3.09
36	Carbonates, limed once; ¼ soda, ¼ potash	227	1.45	3.07
27	Carbonates, limed once; 1 soda, ¼ potash	269	1.47	3.33
48	Carbonates, limed thrice; ¼ soda, ¼ potash	246	1.30	3.28
39	Carbonates, limed thrice; 1 soda, ¼ potash	372	1.39	2.67
6	Chlorids, limed once; ½ soda, ½ potash	390	1.29	2.41
2	Chlorids, limed once; 1 soda, ½ potash	402	1.42	2.80
18	Chlorids, limed thrice; ½ soda, ½ potash	340	1.26	2.64
14	Chlorids, limed thrice; 1 soda, ½ potash	377	1.26	2.46
30	Carbonates, limed once; ½ soda, ½ potash	311	1.41	2.77
26	Carbonates, limed once; 1 soda, ½ potash	385	1.42	2.54
23	Chlorids, limed thrice; ¾ soda, ¾ potash	376	1.33	2.51
13	Chlorids, limed thrice; 1 soda, ¾ potash	371	1.23	2.24
47	Carbonates, limed thrice; ¾ soda, ¾ potash	404	1.41	2.60
37	Carbonates, limed thrice; 1 soda, ¾ potash	392	1.38	2.42
22	Chlorids, limed thrice; 0 soda, 1 potash	369	1.28	2.55
20	Chlorids, limed thrice; ½ soda, 1 potash	392	1.28	2.22
17	Chlorids, limed thrice; 1 soda, 1 potash	382	1.31	2.32
34	Carbonates, limed once; 0 soda, 1 potash	414	1.40	2.53
32	Carbonates, limed once; ½ soda, 1 potash	420	1.41	2.22
29	Carbonates, limed once; 1 soda, 1 potash	358	1.40	2.40
46	Carbonates, limed thrice; 0 soda, 1 potash	384	1.31	2.52
44	Carbonates, limed thrice; ½ soda, 1 potash	399	1.43	2.59
41	Carbonates, limed thrice; 1 soda, 1 potash	394	1.42	2.45

There seems in the foregoing table to be no definite nor constant relationship between the percentages of phosphoric acid and of nitrogen, nor between either one and the yields. In ten of the eleven instances where comparisons are permissible between the carbonates and chlorids there was a higher percentage of phosphoric acid in the crops where the carbonates were employed, and in the eleventh case the percentages were identical.

In each of the four cases when a quarter ration each of sodium and potassium salt was supplemented by an additional three-quarter ration of sodium salt the yield was greatly increased. At the same time the percentages of phosphoric acid in the crops ranged from .02 to .09 greater than where additional sodium was not present.

When a half ration each of potassium and sodium salt was supplemented by an additional half ration of sodium salt the crops were increased 12, 37, and 74 pounds, but in only one of the three instances was there a sufficiently greater percentage of phosphoric acid in the crop to have any significance.

When a three-quarter ration of each salt was supplemented by an additional quarter ration of sodium salt the yields, and the percentages of phosphoric acid, were in both cases less than where it was not added.

In the six instances when a full ration of potassium salt was supplemented by either a half or a full ration of sodium salt the yields, and percentages of phosphoric acid, were such as to furnish no evidence that there had been a positive gain in yield or in the percentage of phosphoric acid as a consequence of adding the sodium salt. These results are chiefly of interest when compared with those secured when the supply of potassium salt was small, for in the latter case the yield and the percentage of phosphoric acid in the crop were both increased by the application of further sodium salt in the manures.

The important point to be considered is whether the increased yields just mentioned were the result of the higher percentages of phosphoric acid or whether the latter were merely incidental accom-

paniments of the increased yields. When the quarter ration of each salt was used the yields were 240, 192, 227, and 246 pounds, with 1.32, 1.29, 1.45, and 1.30 as the accompanying percentages of phosphoric acid. Upon the addition of the three-quarter ration of sodium salt the corresponding yields rose to 373, 294, 269, and 372 pounds and the percentages of phosphoric acid to 1.39, 1.35, 1.47, and 1.39, respectively.

Upon comparing the other results in the table it will be seen, however, that there are several instances in which yields greater than any of those mentioned above were produced with smaller, or essentially as small, percentages of phosphoric acid. The yields here cited were furthermore all of them what would be properly considered as normal. The evidence afforded does not, therefore, fully uphold the idea that the yields were increased as the direct result of the presence of the higher percentages of phosphoric acid in the crop, but much evidence is afforded that the increase was due, possibly, to some direct function of sodium which it was capable of exercising in the absence of an abundance of potassium. The possible influence of the sodium salts upon the osmotic pressure, upon the reaction of the medium in which the plants are grown, and upon other factors is being studied by way of water culture, and these results will be published later.

Other results secured with the same kind of flat turnips in another experiment are of interest in this connection, particularly for the reason that the turnips were growing at the same time and were harvested shortly after those which have just been discussed. The soil in this permanent plat, (No. 45) was manured uniformly with phosphoric acid, potash, and nitrogen. In one instance the phosphoric acid was supplied in guano, in another in acid phosphate, and in a third in fine ground bone. The yields from the same areas as those given above were 406, 395, and 374 pounds, respectively, and the corresponding percentages of phosphoric acid were 0.93, 1.01, and 1.02. It will be seen that these yields were all above those obtained where the quarter ration of each salt was supplemented by

a three-quarter ration of sodium salt, and at the same time the percentages of phosphoric acid in the dry matter of the crop were much less than in the cases which have just been considered. This still further lends support to the idea that the higher percentages of phosphoric acid accompanying the increased yields produced by the additional sodium salt were not the actual cause of the increased yields, but that they were merely an incidental accompaniment, due possibly to the solvent action upon the phosphates within the soil or to the ability of the plant to most easily take up phosphoric acid when it is combined with potassium or sodium.

With the hope of throwing additional light upon the relative influence of sodium and potassium salts on the percentages of nitrogen and phosphoric acid in certain crops, samples for analysis were taken from plats where a quarter ration of sodium was employed together with a full ration of potassium, and on the other hand from plats where a full ration of sodium salt was supplemented by a quarter ration of potassium salt. The results of these analyses are given below:

Radish, White Strasburg, Roots. 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Phosphoric acid.	Per cent. in dry matter. Nitrogen.
3	Chlorids, limed once; 1 soda, ¼ potash	456	1.10	3.50
9	Chlorids, limed once; ¼ soda, 1 potash	547	1.17	3.52
15	Chlorids, limed thrice; 1 soda, ¼ potash	438	1.08	4.11
21	Chlorids, limed thrice; ¼ soda, 1 potash	511	1.32	3.82
27	Carbonates limed once; 1 soda, ¼ potash	400	1.26	4.10
33	Carbonates limed once; ¼ soda, 1 potash	557	1.19	3.69
39	Carbonates limed thrice; 1 soda, ¼ potash	398	1.16	3.87
45	Carbonates, limed thrice; ¼ soda, 1 potash	522	1.08	3.51

It will be observed that, so far as concerns phosphoric acid, the percentages were in two cases higher where the larger amount of sodium salt was used. In the other two cases the percentages of phosphoric acid were lower, even though the yields were smaller in all four instances. In all but one of the four instances higher percentages of nitrogen accompanied the use of the larger proportion of sodium salts; yet, nevertheless, the crops were in all cases much smaller than where the larger proportion of potassium salt was applied. There is no good evidence that the excess of nitrogen inhibited growth, and still less that the phosphoric acid did so; but on the contrary, the limit to the size of the crop seems to have been determined chiefly by the supply of potassium, though, as had been abundantly shown by the experiments described elsewhere, sodium materially increases the crop when the supply of potassium is insufficient for its needs. The results with the English, or flat, turnip, which was also grown in the year 1905, will now be considered.

English, or Flat Turnip, Roots, 1905.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter. Phosphoric acid.	Nitrogen.
3	Chlorids, limed once; 1 soda, ½ potash...........	373	1.39	2.90
9	Chlorids, limed once; ½ soda, 1 potash...........	413	1.15	2.49
15	Chlorids, limed thrice; 1 soda, ½ potash..........	294	1.35	3.09
21	Chlorids, limed thrice; ½ soda, 1 potash..........	406	1.26	2.29
27	Carbonates, limed once; 1 soda, ½ potash.........	269	1.47	3.33
33	Carbonates, limed once; ½ soda, 1 potash.........	402	1.09	2.35
39	Carbonates, limed thrice; 1 soda, ½ potash........	372	1.39	2.67
45	Carbonates, limed thrice; ½ soda, 1 potash........	344	1.23	2.74

It will be observed, in the case of the turnip, that in all four instances the percentages of phosphoric acid were unmistakably

greater when the larger amount of sodium salt was used. The same was also true of the nitrogen, excepting in the last instance. The fact that greater yields accompanied smaller percentages of nitrogen and of phosphoric acid in three of the four cases can not be considered as furnishing evidence that the nitrogen and phosphoric acid inhibited growth, but that the growth was limited, as in the case of the radish, by the shortage of potassium. It would certainly be of much interest to ascertain if the extra phosphorus found in these plants in consequence of the employment of sodium salts is in inorganic or organic combinations within the plant, for in view of the recent work by Jordan, Hart, and Patten,* and by Tunnicliffe,† it might in some cases have marked influence upon the function of the plant as concerns its food value.

It may be seen by reference to the relative amounts of proteid and non-proteid nitrogen in the turnip roots (page 220), that a smaller proportion of proteid nitrogen accompanied an increase in the percentages of both phosphoric acid and nitrogen when the larger proportion of sodium was used, and that in the one instance where phosphoric acid only was increased the proportion of proteid and non-proteid nitrogen remained unchanged. These results, although too limited in number to be more than suggestive, certainly indicate that the increased percentages of phosphoric acid and nitrogen may not have increased the feeding value of the crop.

Concerning the Influence of Sodium and Potassium upon the Relative Percentages of Proteid and Non-Proteid Nitrogen.

In order to form some idea as to the influence of sodium and potassium upon the relative percentages of proteid and non-proteid nitrogen present in the crops, a few determinations were made for this purpose. The data are not sufficient to be conclusive, but are rather to be looked upon as suggestive until opportunity may be afforded us or others to pursue the subject further.

*Technical Bulletin No. 1, N. Y. Agr. Experiment Station, Geneva.

†Arch. Internat. Pharmacop. et Thér. 16 (1906), No. 1–4, pp. 207–220, Abs. E. S. R. 18, p. 359.

The non-proteid nitrogen given below includes nitrogen in nitrates in amounts approximating 0.9 per cent. of the dry matter in the case of the radish and about half that quantity in the case of the turnips. In addition to these data it is desirable that determinations be made in order to ascertain the relative amounts of nitrate and of amido nitrogen in the individual cases, but the time at disposal has rendered this as yet impossible.

Below are given the analytical data which were secured:

Per cent. of Nitrogen in Different Combinations in the Dry Matter of the Roots (Crop of 1905).

Kind of Crop and of Sodium and Potassium Salts Used.	LIMED ONCE.				LIMED THREE TIMES.			
	1 soda, ½ potash.	Relative percentages of the total nitrogen in the two groups.	½ soda, 1 potash.	Relative percentages of the total nitrogen in the two groups.	1 soda, ½ potash.	Relative percentages of the total nitrogen in the two groups.	½ soda, 1 potash.	Relative percentages of the total nitrogen in the two groups.
Plat No.	3	3	9	9	15	15	21	21
Turnip Roots. Chlorids.								
Total nitrogen	2.90	......	2.49	......	3.09	......	2.29	......
Proteid nitrogen†	*	*	*	*	1.55	50.2	1.43	62.4
Non-proteid nitrogen	*	*	*	*	1.54	49.8	0.86	37.6
Plat No.	27	27	33	33	39	39	45	45
Turnip Roots. Carbonates.								
Total nitrogen	3.33	......	2.35	......	2.67	......	2.74	......
Proteid nitrogen	1.49	44.7	1.36	57.9	1.46	54.7	1.49	54.4
Non-proteid nitrogen	1.84	55.3	0.99	42.1	1.21	45.3	1.25	45.6
Plat No.	3	3	9	9	15	15	21	21
Radish Roots. Chlorids.								
Total nitrogen	3.50	......	3.52	......	4.11	......	3.82	......
Proteid nitrogen	1.36	38.8	1.48	42.1	1.49	36.3	1.35	35.3
Non-proteid nitrogen	2.14	61.2	2.04	57.9	2.62	63.7	2.47	64.7

*Not determined. †Determined by the official method of the A. O. A. C.

In the case of the turnip crops from plats Nos. 15 and 21 it will be seen that 62.4 per cent. of the total nitrogen was in the proteid combination when the full ration of potassium and quarter ration of sodium were employed, but in the instance when a full ration of sodium and a quarter ration of potassium were used it will be seen that only 50.2 per cent. of the total nitrogen was in proteid combinations. Quite similar results were secured in the case of the crops from plats Nos. 27 and 33. Also with the radish roots from plats Nos. 3 and 9 the results pointed in the same direction, though the difference was small. In the case of the turnips from plats Nos. 29 and 45 and of the radishes from plats Nos. 15 and 21 the results were practically alike, though in the latter case pointing slightly in the opposite direction from those first mentioned above. In view of the tendency of sodium salts to increase the percentage of phosphorus in certain of the plants which have been employed in these experiments, particularly when the supply of potassium was small, it would seem desirable that this question should be studied further in order that more conclusive data on this point may be secured.

In concluding the discussion of this phase of the results with the sodium salts it may be said that, as a whole, they show that the use of sodium carbonate and potassium carbonate has been followed as a rule by higher percentages of phosphoric acid in the crop than the use of the chlorids.

It has been very conclusively shown in the field that, in the presence of limited supplies of potassium salts, sodium salts are important factors in increasing the yields of certain crops. This was particularly striking in the case of the mangel-wurzel, even when a very large quantity of potassium was employed.

The results show in a most conclusive manner that by the employment of sodium salts, particularly where the supply of potash is limited, the percentages of phosphorus in the crop are notably increased. Much evidence has also been deduced to show that the increased crops accompanying the employment of sodium salts under the circumstances mentioned were not in consequence of the presence

of larger amounts of phosphoric acid in the plant, but that the gain was possibly due to a direct physiological function of the sodium or to other causes which will be discussed in a later publication.

No constant nor definite relationship has been observed between the percentages of phosphoric acid and nitrogen in the crops. This has been somewhat of a surprise in view of the frequent references in the agricultural literature to the effect that "the phosphorus goes with the nitrogen," yet this may have been due in part to our having dealt chiefly with root crops. It is possible that further light may be thrown upon this point when it becomes convenient to determine more fully the individual nitrogenous compounds of these crops, a work that is in prospect, in connection with a careful study of the influence of sodium salts upon the organic constituents of plants.

Could the Frequent Beneficial Effect of Sodium Salts Have Been due to Their Enabling the Plant to Take up Additional Lime or Magnesia?

It becomes important, in connection with a discussion of the reason for the beneficial action of sodium salts in these experiments, to consider whether any part of the benefit can, under the circumstances, be attributed to a "setting free" of lime or magnesia.

Below are given the yields of Strasburg radish upon the same area basis as those given previously in connection with the discussion of the nitrogen and phosphoric acid percentages. Accompanying these are the respective percentages of lime and magnesia found in the dry matter of the crops.

Radish, White Strasburg, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
12	Chlorids, unlimed; ¼ soda, ¼ potash	547	1.38	0.73
3	Chlorids, unlimed; 1 soda, ¼ potash,	709	1.09	0.67
24	Chlorids, limed; ¼ soda, ¼ potash	432	1.56	1.02
15	Chlorids, limed; 1 soda, ¼ potash	685	1.19	0.73
36	Carbonates, unlimed; ¼ soda, ¼ potash	547	1.17	0.77
27	Carbonates, unlimed; 1 soda, ¼ potash	722	1.27	0.94
48	Carbonates, limed; ¼ soda, ¼ potash	432	1.53	1.17
39	Carbonates, limed; 1 soda, ¼ potash	540	1.07	0.76
6	Chlorids, unlimed; ½ soda, ½ potash	797	1.02	0.65
2	Chlorids, unlimed; 1 soda, ½ potash	834	1.06	0.58
18	Chlorids, limed; ½ soda, ½ potash	662	1.43	0.56
14	Chlorids, limed; 1 soda, ½ potash	766	1.32	0.63
30	Carbonates, unlimed; ½ soda, ½ potash	776	1.24	0.75
26	Carbonates, unlimed; 1 soda, ½ potash	817	1.23	0.90
42	Carbonates, limed; ½ soda, ½ potash	621	1.19	0.72
38	Carbonates, limed; 1 soda, ½ potash	662	1.17	0.67

It will be observed that in three of the four cases where a quarter ration of each salt was supplemented by the addition of a three-quarter ration of sodium salt to the great advantage of the crop, that the percentages of both lime and magnesia were less than where less soda was employed. It will also be seen that the benefit was apparently not due to changes in the relative amounts of lime and magnesia taken up by the crop, as might be suggested by one familiar with the work of Loew and his fellow-workers, since these changes were not of such a character nor of such a degree as to explain the

Carrot, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash	343	0.78	0.39
15	Chlorids, limed; 1 soda, ¼ potash	483	0.74	0.32
48	Carbonates, limed; ¼ soda, ¼ potash	373	0.70	0.41
39	Carbonates, limed; 1 soda, ¼ potash	483	0.68	0.35

It will be seen that in the case of the carrot the percentages of lime and magnesia were lessened in every instance where the quarter ration of each salt was further supplemented by a three-quarter ration of sodium salt, even notwithstanding the greater yields.

No ground for benefit to the crop by virtue of a liberation of lime and magnesia is afforded by the results, nor does it seem probable that the relatively smaller percentage of magnesia could have been responsible for the increased yields.

The following results were secured with chicory:

Chicory, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash	200	0.22	0.25
15	Chlorids, limed; 1 soda, ¼ potash	189	0.24	0.25
48	Carbonates, limed; ¼ soda, ¼ potash	234	0.25	0.32
39	Carbonates, limed; 1 soda, ¼ potash	205	0.26	0.32

It will be at once observed that the yields were lower in both cases where the additional amount of sodium salt was used, the percentages of magnesium oxid were identical, and those of calcium oxid showed no significant differences.

The following results were obtained with the white Strasburg radish, which was grown in the year 1901:

Radish, White Strasburg, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Calcium oxid.	Magnesium oxid.
22	Chlorids, limed; 0 soda, 1 potash	248	1.10	0.64
20	Chlorids, limed; ½ soda, 1 potash	261	1.13	0.66
19	Chlorids, limed; ¾ soda, 1 potash	243	1.00	0.53
34	Carbonates, unlimed; 0 soda, 1 potash	288	0.96	0.57
32	Carbonates, unlimed; ½ soda, 1 potash	291	0.95	0.59
31	Carbonates, unlimed; ¾ soda, 1 potash	279	0.84	0.50
46	Carbonates, limed; 0 soda, 1 potash	228	1.08	0.58
44	Carbonates, limed; ½ soda, 1 potash	252	0.86	0.51
43	Carbonates, limed; ¾ soda, 1 potash	243	0.89	0.57
12	Chlorids, unlimed; ¼ soda, ¼ potash	234	1.13	0.65
3	Chlorids, unlimed; 1 soda, ¼ potash	216	0.90	0.53

When a sodium salt was employed in addition to a full ration of potassium salt there was no positive evidence of an increase in yield due to this fact, excepting possibly where only an extra half ration of sodium salt was added. In the single comparison of a quarter ration each of the potassium and of the sodium salt with the same supplemented by a three-quarter ration of sodium salt, the yield was less when the amount of the latter salt was increased.

There was some slight evidence of a tendency of the sodium salts

to lower the percentages of magnesium oxid, and still stronger evidence of a lowering of the percentages of calcium oxid.

The following results were obtained with chicory roots grown in 1901:

Chicory, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Calcium oxid.	Magnesium oxid.
22	Chlorids, unlimed; 0 soda, 1 potash..............	243	0.24	0.17
20	Chlorids, unlimed; ½ soda, 1 potash..............	243	0.24	0.17
19	Chlorids, unlimed; ¾ soda, 1 potash..............	243	0.24	0.16
34	Carbonates, unlimed; 0 soda, 1 potash...........	162	0.23	0.17
32	Carbonates, unlimed; ½ soda, 1 potash...........	180	0.24	0.15
31	Carbonates, unlimed; ¾ soda, 1 potash...........	194	0.24	0.16
24	Chlorids, limed; ¼ soda, ¼ potash................	194	0.22	0.24
15	Chlorids, limed; 1 soda, ¼ potash................	225	0.23	0.24
48	Carbonates, limed; ¼ soda, ¼ potash.............	131	0.21	0.26
39	Carbonates, limed; 1 soda, ¼ potash.............	117	0.24	0.27
	Chicory, Tops, 1901.			
48	Carbonates, limed; ¼ soda, ¼ potash.............	*	2.71	1.81
39	Carbonates, limed; 1 soda, ¼ potash.............	*	2.22	1.11

*Weight not determined.

The addition of a sodium salt to a full ration of potassium salt was accompanied by an apparent gain in the crop of chicory roots in but one of the two series. No depression of the calcium oxid in the plant, and only suggestions of a possible depression of the magnesium oxid, followed the introduction of the sodium salt in the manures.

The addition to a quarter ration of each salt of an extra three-

quarter ration of the sodium salt resulted in a greater yield in one case and in a smaller yield in the other case.

No marked influence of the sodium salt upon the percentages of calcium oxid and of magnesium oxid seemed to have resulted.

In the case of the chicory tops the percentages of both magnesium and calcium oxids were decidedly and unquestionably lessened as a consequence of increasing the application of sodium salt, and the ratio of magnesia to lime in the tops was changed from 1: 1.5 to 1:2. Whether this change in the ratio affected the growth favorably or unfavorably remains to be determined.

Below are given the results secured with the carrot crop, which was grown in the year 1901:

Carrot, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash	315	0.50	0.32
15	Chlorids, limed; 1 soda, ¼ potash	313	0.51	0.27
48	Carbonates, limed; ¼ soda, ¼ potash	315	0.50	0.30
39	Carbonates, limed; 1 soda, ¼ potash	306	0.51	0.35
	Carrot, Tops, 1901.			
48	Carbonates, limed; ¼ soda, ¼ potash	*	1.87	0.96
39	Carbonates, limed; 1 soda, ¼ potash	*	1.54	0.89

*Not weighed.

No gain in carrot roots resulted when a three-quarter ration of sodium salt was added to a quarter ration of each.

The contradictory and trifling differences in the percentages of magnesium oxid and calcium oxid are such that no definite relation-

ship between them and the amount of sodium salt in the manures can be established.

In the case of the tops, just as with the chicory tops, the employment of a larger amount of the sodium salt was followed by a depression of the percentages of calcium and magnesium oxids. The ratio of magnesia to lime was changed but about .2 in this instance, and in a direction opposite to that of the change in the case of the chicory tops.

The results in connection with the white Strasburg radish, raised in the year 1905, are given below:

Radish, White Strasburg, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Calcium oxid.	Per cent. in dry matter. Magnesium oxid.
12	Chlorids, limed once; ¼ soda, ¼ potash	398	1.69	0.79
3	Chlorids, limed once; 1 soda, ¼ potash	456	1.42	0.69
24	Chlorids, limed thrice; ¼ soda, ¼ potash	324	1.87	0.83
15	Chlorids, limed thrice; 1 soda, ¼ potash	438	1.59	0.78
36	Carbonates, limed once; ¼ soda, ¼ potash	372	1.66	0.80
27	Carbonates, limed once; 1 soda, ¼ potash	400	1.58	0.78
48	Carbonates, limed thrice; ¼ soda, ¼ potash	375	1.67	0.80
39	Carbonates, limed thrice; 1 soda, ¼ potash	398	1.52	0.76
11	Chlorids, limed once; ¾ soda, ¾ potash	557	1.31	0.71
1	Chlorids, limed once; 1 soda, ¾ potash	550	1.21	0.44
23	Chlorids, limed thrice; ¾ soda, ¾ potash	498	1.53	0.59
13	Chlorids, limed thrice; 1 soda, ¾ potash	547	1.34	0.66
35	Carbonates, limed once; ¾ soda, ¾ potash	553	1.08	0.70
25	Carbonates, limed once; 1 soda, ¾ potash	556	1.20	0.64

Radish, White Strasburg, Roots, 1905.—Concluded.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
47	Carbonates, limed thrice; ¾ soda, ¾ potash	514	1.32	0.65
37	Carbonates, limed thrice; 1 soda, ¾ potash	555	1.37	0.59
10	Chlorids, limed once; 0 soda, 1 potash	522	1.12	0.83
8	Chlorids, limed once; ½ soda, 1 potash	542	1.18	0.58
5	Chlorids, limed once; 1 soda, 1 potash	574	1.00	0.76
22	Chlorids, limed thrice; 0 soda, 1 potash	522	1.28	0.95
20	Chlorids, limed thrice; ½ soda, 1 potash	553	1.52	0.73
34	Carbonates, limed once; 0 soda, 1 potash	548	1.03	0.85
32	Carbonates, limed once; ½ soda, 1 potash	555	1.23	0.62
46	Carbonates, limed thrice; 0 soda, 1 potash	508	1.30	0.85
41	Carbonates, limed thrice; 1 soda, 1 potash	532	1.24	0.79

In all four instances where a quarter ration each of the two salts was supplemented by a three-quarter ration of sodium salt unmistakable gains in the crops resulted and the percentages of both calcium and magnesium oxids were lessened in all four cases in consequence of its addition, but the ratios between the two remained practically unchanged.

Where a three-quarter ration each of the two salts was supplemented by an additional quarter ration of sodium salt no positive advantage resulted. The yields were greater in three of the four cases, though in one of these cases the difference was wholly insignificant. The percentages of magnesium oxid in the plants were lessened by the soda in three of the four cases, but the same was true of the calcium oxid in only two of the cases.

Where a full ration of potassium salt was supplemented by a half ration of sodium salt the yields were a little greater in every one of

the three cases. The percentage of calcium oxid was increased in each of the three instances, but the per cent. of magnesium oxid was decreased in every case.

This lessening of the magnesia in its relation to the lime is of special interest in view of the increased crop and in view of the injury to the crop in every case by extra liming. The magnesia-lime relationship idea of Loew would seem to fail in this case to explain the benefit from the soda, particularly in view of the fact that liming increased the percentage of calcium oxid in the crop.

The results secured with the English, or flat, turnip, which was grown in the year 1905, are given below:

Turnip, Flat, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Calcium oxid.	Magnesium oxid.
12	Chlorids, limed once; ¼ soda, ¼ potash	240	0.99	0.40
3	Chlorids, limed once; 1 soda, ¼ potash	373	0.87	0.31
24	Chlorids, limed thrice; ¼ soda, ¼ potash	192	1.17	0.38
15	Chlorids, limed thrice; 1 soda, ¼ potash	294	0.99	0.37
36	Carbonates, limed once; ¼ soda, ¼ potash	227	1.04	0.40
27	Carbonates, limed once; 1 soda, ¼ potash	269	0.90	0.38
48	Carbonates, limed thrice; ¼ soda, ¼ potash	246	1.15	0.41
39	Carbonates, limed thrice; 1 soda, ¼ potash	372	0.89	0.39
6	Chlorids, limed once; ½ soda, ½ potash	390	0.83	0.37
2	Chlorids, limed once; 1 soda, ½ potash	402	0.80	0.35
18	Chlorids, limed thrice; ½ soda, ½ potash	340	1.00	0.35
14	Chlorids, limed thrice; 1 soda, ½ potash	377	0.93	0.36
30	Carbonates, limed once; ½ soda, ½ potash	311	1.00	0.36
26	Carbonates, limed once; 1 soda, ½ potash	385	0.87	0.36

Turnip, Flat, Roots, 1905.—Concluded.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
23	Chlorids, limed thrice; ¼ soda, ¼ potash	376	1.02	0.33
13	Chlorids, limed thrice; 1 soda, ¼ potash	371	0.90	0.38
47	Carbonates, limed thrice; ¼ soda, ¼ potash	404	0.88	0.37
37	Carbonates, limed thrice; 1 soda, ¼ potash	392	0.92	0.38
22	Chlorids, limed once; 0 soda, 1 potash	369	0.98	0.50
20	Chlorids, limed once; ½ soda, 1 potash	392	1.03	0.41
17	Chlorids, limed once; 1 soda, 1 potash	382	0.91	0.36
34	Carbonates, limed once; 0 soda, 1 potash	414	0.78	0.46
32	Carbonates, limed once; ½ soda, 1 potash	420	0.81	0.34
29	Carbonates, limed once; 1 soda, 1 potash	358	0.90	0.35
46	Carbonates, limed thrice; 0 soda, 1 potash	384	0.88	0.42
44	Carbonates, limed thrice; ½ soda, 1 potash	399	0.89	0.41
41	Carbonates, limed thrice; 1 soda, 1 potash	394	0.74	0.46

When the quarter ration of each salt was supplemented by an additional three-quarter ration of the sodium salt, the yields were considerably greater in all four cases. The percentages of calcium and magnesium oxids, on the contrary, were lessened in each instance. In three cases the ratio between lime and magnesia was materially changed and in the other case not; hence the gain in all cases can not be attributable to this fact.

In the cases given where a half ration each of the two salts was supplemented by an application of a half ration of sodium salt the yields were only moderately increased, and in one case only was the ratio of magnesia to lime practically reduced. The absolute percentages of magnesium oxid were not positively affected, but in all three instances the percentages of calcium oxid were depressed by the extra sodium salt.

A three-quarter ration each of the sodium and potassium salts seemed to be sufficient to nullify the good effects of further amounts of sodium salts, for in both instances where an additional quarter ration of the sodium salt was applied the yields were slightly less than without it. When the additional sodium salt was used the percentages of magnesium oxid in the dry matter were in both cases slightly increased. The same was true of the calcium oxid in but one case, while in the other instance the reverse was true.

The supplementing of a full ration of potassium salt with a half ration of sodium salt was accompanied in all three cases by slightly greater yields, but the addition of a full ration of sodium salt was not always accompanied by an increase of crop. Many of these differences were, however, too small to have much significance. The percentages of calcium and magnesium oxid exhibit much irregularity and do not show the same positive depressing effect of the sodium salt which was observed when only quarter or half rations of each salt were employed.

In conclusion it may be said that the foregoing results fail to give evidence that the sodium salts were probably beneficial by virtue of their setting free additional amounts of either calcium or magnesium oxids, and it seems also improbable that the benefit observed could have been due to changes in the relative amounts of lime and magnesia taken up by the plants.

DATA CONCERNING THE INFLUENCE OF SODIUM AND POTASSIUM SALTS UPON THE GROWTH OF CERTAIN PLANTS AND UPON THE PERCENTAGES OF SODIUM AND POTASSIUM OXIDS IN THE DRY MATTER.

The results about to be described were obtained upon the same plats of land as those which have been mentioned previously, hence further attention here to the scheme of manuring, excepting in so far as it concerns the respective potassium and sodium salts, is unnecessary.

The following results were obtained in the year 1898:

Millet, Golden, 1898.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
36	Carbonates, unlimed; ¼ soda, ¼ potash	132	0.14	1.09
27	Carbonates, unlimed; 1 soda, ¼ potash	102	0.17	0.97
48	Carbonates, limed; ¼ soda, ¼ potash	142	0.05	1.16
39	Carbonates, limed; 1 soda, ¼ potash	155	0.07	1.09

In the case of the millet the yield was in one instance greater and in the other less where the extra amount of sodium salt was added.

In each instance the percentage of sodium oxid was increased and that of potassium oxid lessened when the extra three-quarter ration of the sodium salt was employed. The lack of positive evidence of benefit to the yield from the employment of an additional amount of sodium salt and the small quantities of sodium oxid found in the millet in any case furnish a striking contrast to the results secured with certain other varieties of plants.

Below are given the data secured with the white Strasburg radish in 1899:

Radish, White Strasburg, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
12	Chlorids, unlimed; ¼ soda, ¼ potash	547	3.83	3.69
3	Chlorids, unlimed; 1 soda, ¼ potash	709	6.38	3.76
24	Chlorids, limed; ¼ soda, ¼ potash	432	4.03	3.62
15	Chlorids, limed; 1 soda, ¼ potash	685	6.01	2.85
36	Carbonates, unlimed; ¼ soda, ¼ potash	547	3.56	3.05
27	Carbonates, unlimed; 1 soda, ¼ potash	722	6.57	2.90
48	Carbonates, limed; ¼ soda, ¼ potash	432	3.69	3.61
39	Carbonates, limed; 1 soda, ¼ potash	540	6.50	2.81
6	Chlorids, unlimed; ½ soda, ½ potash	797	3.67	6.12
2	Chlorids, unlimed; 1 soda, ½ potash	834	4.14	6.72
18	Chlorids, limed; ½ soda, ½ potash	662	3.62	5.54
14	Chlorids, limed; 1 soda, ½ potash	766	5.12	5.19
30	Carbonates, unlimed; ½ soda, ½ potash	776	3.60	5.59
26	Carbonates, unlimed; 1 soda, ½ potash	817	4.50	4.98
42	Carbonates, limed; ½ soda, ½ potash	621	4.07	5.48
38	Carbonates, limed; 1 soda, ½ potash	662	5.72	5.27

It will be observed that the yields were increased 162, 253, 175, and 108 pounds where the quarter rations of the two salts were supplemented by a three-quarter ration of sodium salt. Expressed in another way, the gains amounted to 30, 69, 32, and 22 per cent.

It will be seen that in all four instances the percentages of sodium oxid in the plant were greatly increased where the extra application of the sodium salt had been made. In three of the four instances a depression of the percentage of potassium oxid was also observed. In the case of the crops from plats Nos. 15 and 24 the percentage

of potassium oxid in one instance was 3.62, but where an extra application of a three-quarter ration of sodium salt was made the per cent. of potassium oxid was but 2.85. In the case of the crops from plats 39 and 48 the percentage of potassium oxid was depressed from 3.61 to 2.81. In both of these cases of marked depression of the potash, the land had been limed.

Where a half ration of sodium salt was added to a half ration each of potassium and sodium salts, the yields were greater in all four instances. In every instance where the extra sodium salt was employed the per cent. of sodium oxid in the crop was very decidedly increased. At the same time the per cent. of potassium oxid was depressed in three of the four cases. In other words, very much larger crops were produced in all but two of the cases with the smaller percentages of potassium oxid in the crop. It appears, therefore, that the larger percentages of potassium oxid which were met with in the crop were therefore not necessary to its production, at least provided a liberal supply of sodium was present in the manures. The question therefore arises why the larger amount of potassium actually in the crop was not utilized to advantage when the extra sodium salt was not employed. Furthermore, the fact that larger crops resulted and that a more effective use was made of the potassium supply when the quantity of sodium salt in the manures was increased is certainly a very suggestive feature.

When these results are considered in connection with the yields where larger amounts of potassium salts were used,* it will be seen that the advantage of employing the sodium salt seemed to become less as the potassium salt in the manures was increased. The fact that on account of the greater yields larger total amounts of potassium oxid were usually removed per acre where the extra sodium salt was employed in no way lessens the evidence that the sodium salt had probably proved highly beneficial in some other way than as an agent in liberating potassium.

The results with the English or flat, turnip in 1899 now follow:

* Bul. 104 R. I. Agl. Expt. Station (1905) p. 77.

Turnip, Flat, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash................	214	2.37	2.88
15	Chlorids, limed; 1 soda, ¼ potash.................	293	5.05	2.13
36	Carbonates, unlimed; ¼ soda, ¼ potash...........	149	2.88	2.54
27	Carbonates, unlimed; 1 soda, ¼ potash...........	212	2.31	3.21

The addition of a three-quarter ration of sodium salt to the quarter ration of the two salts resulted in gains of 37 and 42 per cent. in turnip roots. In the case of plats Nos. 24 and 15 the percentage of sodium oxid in the plant was increased and of the potassium oxid decreased in consequence of the addition of the extra sodium salt. The case of plats Nos. 27 and 36 shows exactly the reverse. These results, particularly as concerns the sodium oxid, are so unusual as to arouse a suspicion that there may have been an interchange of the samples from the two plats. It may, nevertheless, be attributable to some obscure cause. A similar observation will be referred to later in connection with the same crop in 1905 (plats Nos. 39 and 48).

Below are given results secured with the mangel-wurzel (Norbiton giant beet), in 1899:

Beet, Norbiton Giant, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Sodium oxid.	Potassium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash	421	2.65	1.24
15	Chlorids, limed; 1 soda, ¼ potash	682	4.63	0.84
48	Carbonates, limed; ¼ soda, ¼ potash	299	2.92	1.10
39	Carbonates, limed; 1 soda, ¼ potash	601	5.10	0.81

The employment of an extra three-quarter ration of sodium salt to supplement the quarter rations of the two salts resulted in a gain in the yield of beets amounting to 62 per cent. in one case and to over 100 per cent. in the other case. The results agree with those obtained with the radish in showing a greatly increased percentage of sodium oxid and a decreased percentage of potassium oxid as a result of the use of the extra sodium salt.

In view of the fact that, with percentages of .81 and .84 of potassium oxid, crops amounting to 601 and 682 pounds were produced, it is rather surprising that where higher percentages of potassium oxid were present the crops should have been so much smaller, unless some special physiological function is ascribed to the sodium salt. This view of the matter is still further reinforced by the results in connection with the radish. Furthermore, in two cases with the radish, increased yields and percentages of potassium oxid accompanied the use of sodium salts. It would appear, therefore, that the claim can not be logically made in this case that the amounts of potassium oxid which equalled 1.10 and 1.24 per cent. were sufficient to, or probably did, inhibit growth. It is, of course, recognized that the sodium salt may have affected beneficially the moisture conditions of the soil, the osmotic pressure of the soil solution, or other physical or biological soil factors, yet the influence upon these would

hardly seem to be sufficient to explain the increased yields. It will be borne in mind that it has already been shown in another connection that the sodium salt is a powerful factor in aiding the transportation of phosphorus into the plant, but at the same time it was shown that the extra phosphorus was apparently an accompaniment of the increased crops rather than a cause of the increase.

Below are given results with the carrot obtained in connection with the crop of 1899:

Carrot, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
24	Chlorids, limed; ½ soda, ½ potash	343	3.00	2.09
15	Chlorids, limed; 1 soda, ½ potash	483	3.77	2.11
48	Carbonates, limed; ½ soda, ½ potash	373	2.89	2.36
39	Carbonates, limed; 1 soda, ½ potash	483	3.88	1.30

It will be observed that greatly increased yields, higher percentages of sodium oxid, and in one of the cases a much lower percentage of potassium oxid in the crop resulted when an extra amount of sodium salt was applied in the manures.

The results with chicory, which was grown in the same year, were as follows:

Chicory, Roots, 1899.

Plats No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Sodium oxid.	Potassium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash................	200	0.80	0.48
15	Chlorids, limed; 1 soda, ¼ potash................	189	1.01	0.62
48	Carbonates, limed; ¼ soda, ¼ potash.............	234	0.81	0.45
39	Carbonates, limed; 1 soda, ¼ potash.............	205	1.04	0.37

It will be observed that the yields of chicory stand in marked contrast to those of the beet, turnip, radish, and carrot, for there was a smaller crop of chicory roots in each case when an extra three-quarter ration of the sodium salt was added. Another feature observed in but one or two cases previously, with other crops, was the greater percentage of potassium oxid in one of the crops where the extra amount of sodium salt was employed. It will be observed that the per cent. of sodium oxid was increased in each instance where the extra sodium salt was used.

These results seem to indicate that sodium is a less important factor in connection with chicory than with many other of the root crops. The percentages of potassium oxid and of sodium oxid in the roots were much less than in the case of the radish and turnip.

Results with Various Crops Grown in 1901.

The season of 1901 was quite different from that of 1899; in the former year the rainfall of the month of April amounted to 2.63 inches, that of May to 1.88 inches, that of June to 1.87 inches, and that of July to 2.71 inches, making a total of 9.09 inches.

In 1901 the rainfall for the corresponding months amounted to 8.78, 6.98, 1.32 and 4.05 inches, making a total of 21.13 inches for

the four months. Attention is also called to the fact that the application of acid phosphate was increased in 1901 from 600 pounds to 1,296 pounds per acre. The application of magnesium sulfate was also increased from 420 to 600 pounds per acre. In 1899 the application of carbonate of potash, upon which all of the other applications of potassium and sodium salts were based, amounted to 300 pounds per acre. In 1900 the amount was reduced to 240 pounds, and in 1901 it was further reduced to 210 pounds per acre.

Below are given the results so far as concerns yields and the percentages of potassium oxid and sodium oxid in the dry matter obtained in connection with certain of the crops grown in 1901:

Radish, White Strasburg, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Sodium oxid.	Per cent. in dry matter. Potassium oxid.
22	Chlorids, limed; 0 soda, 1 potash	248	1.43	9.41
20	Chlorids, limed; ½ soda, 1 potash	261	1.95	9.81
19	Chlorids, limed; ¾ soda, 1 potash	243	1.40	11.05
34	Carbonates, unlimed; 0 soda, 1 potash	288	0.91	10.66
32	Carbonates, unlimed; ½ soda, 1 potash	291	1.52	10.73
31	Carbonates, unlimed; ¾ soda, 1 potash	279	1.65	11.55
46	Carbonates, limed; 0 soda, 1 potash	228	0.97	9.42
44	Carbonates, limed; ½ soda, 1 potash	252	1.56	9.21
43	Carbonates, limed; ¾ soda, 1 potash	243	1.60	10.00
12	Chlorids, unlimed; ½ soda, ½ potash	234	3.09	5.42
3	Chlorids, unlimed; 1 soda, ½ potash	216	3.55	6.03

In the limed series receiving chlorids and in the unlimed series receiving carbonates no positive evidence is afforded of benefit to the yield from adding a sodium salt to the full ration of potassium salt. If the results in the limed series receiving carbonates were

considered by themselves it might be concluded that the added sodium salt had been beneficial in the presence of the full ration of potassium salt, but in view of the results which have just been cited it seems more probable that the differences in this latter case were merely incidental and due to an abnormally low yield on plat No. 46.

In two of the three series where the full ration of potassium salt was supplemented by additional amounts of sodium salt there seems to be no escape from the conclusion that the percentage of sodium oxid in the crop was increased. In the third of the series the evidence is inconclusive, because the percentage of sodium oxid in the plants from plat No. 22 appears for some reason to be unusually large. Taken as a whole, the results in the three series go to show that in this particular case the employment of the sodium salt failed to conserve the potassium supply of the soil and manures, but that rather larger amounts of potassium oxid were removed from the soil where the sodium salt had been added.

In striking contrast to the result with the radish in 1899 it will be seen that the yield produced by employing a quarter ration each of the potassium and sodium salt (plat No. 12) was not increased when an additional application of a three-quarter ration of sodium salt was made (plat No. 3). The results agree, however, with those of 1899 in showing an increased percentage of sodium oxid in the crop where a greater amount of sodium salt was added to the soil; yet they are quite the opposite of those of 1899 in showing that more potassium oxid was present in the dry matter of the crop in the case where the additional sodium salt was employed.

In how far these striking contrasts with the results of the year 1899 are due to the smaller size of the radishes, to the increase in the amounts of phosphate and of magnesium sulfate employed, and in what measure they were determined by the greater rainfall remains to be positively ascertained. It is probably true that the heavy rainfall of 1901 and the accompanying lack of clear weather explain the smaller size of the radish roots most satisfactorily, and the

heavy rainfall was also most favorable to a chemical action of the sodium salt upon the potassic compounds of the soil by which the potassium could be rendered available to the plant. Perhaps this latter action alone explains the apparent failure of the sodium salt to act as a conserver of potassium because of more potassium compounds being rendered available and more of the sodium, in consequence of the chemical transformations, passing into less readily soluble combinations. It is also possible that the stage of growth of the plant played some part, though at present this does not seem to have been so important a factor in affecting the results as the unusual amount of rainfall.

Below are given the results secured with chicory:

Chicory, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Sodium oxid.	Per cent. in dry matter. Potassium oxid.
22	Chlorids, limed; 0 soda, 1 potash	243	0.67	1.82
20	Chlorids, limed; ½ soda, 1 potash	243	0.72	1.90
19	Chlorids, limed; ¾ soda, 1 potash	243	0.52	1.97
34	Carbonates, unlimed; 0 soda, 1 potash	162	0.34	2.02
32	Carbonates, unlimed; ½ soda, 1 potash	180	0.51	1.89
31	Carbonates, unlimed; ¾ soda, 1 potash	194	0.52	2.16
24	Chlorids, limed; ¼ soda, ¼ potash	194	0.96	0.63
15	Chlorids, limed; 1 soda, ¼ potash	225	1.18	0.62
48	Carbonates, limed; ¼ soda, ¼ potash	131	0.84	0.55
39	Carbonates, limed; 1 soda, ¼ potash	117	1.19	0.50

Chicory, Tops, 1901.

Plat No.	Special Manures Applied.	Sodium oxid.	Potassium oxid.
48	Carbonates, limed; ¼ soda, ¼ potash	2.29	0.76
39	Carbonates, limed; 1 soda, ¼ potash	3.84	0.97

In the limed chlorid series where the full ration of potassium salt was supplemented by a half and three-quarter ration of sodium salt, it will be seen that the yields were in all cases identical.

In the unlimed series where the carbonates were employed the addition of increasing amounts of the sodium salt was accompanied by an apparent increase in the crop, though these differences may possibly have been merely incidental and hence without significance. In the series first mentioned above, no positive evidence was afforded of an increased percentage of sodium oxid in the crop, and furthermore the percentages of potassium oxid were greater, rather than less, where the extra sodium salt had been used.

In the unlimed carbonate series the percentage of sodium oxid in the roots had been apparently increased by the addition of the sodium salt in the manures. There was, however, owing to the variation in results, no positive evidence of an increase or depression of the percentages of potassium oxid.

In both instances where the manures which contained a quarter ration of each salt were supplemented by an additional three-quarter ration of sodium salt the percentages of sodium oxid in the plant were considerably increased, with but slight or uncertain depression of the potassium oxid. The yield was in one case smaller and in the other larger where the additional sodium salt was employed. These variations were, however, perhaps within the limits of error for such field trials.

In the two instances where the tops were analyzed the sodium oxid and potassium oxid were both found to have been increased in consequence of the employment of a larger amount of sodium salt, yet without an increase in the yield of roots, but on the contrary accompanied by a slightly smaller crop.

No positive benefit to the crop was demonstrated as a result of employing the sodium salts, even when the supply of the potassium salt in the manures was quite limited,* and no evidence was afforded of a conservation of the potassium supply of the soil. On the con-

* See Bul. 106, May, 1905, page 120.

trary, the drain upon the potassium of the soil and manures seems to have been somewhat increased in this instance by the employment of the sodium salt.

Below are given the results secured with the carrot:

Carrot, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Sodium oxid.	Per cent. in dry matter. Potassium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash	315	1.98	1.50
15	Chlorids, limed; 1 soda, ¼ potash	313	2.54	1.45
48	Carbonates, limed; ¼ soda, ¼ potash	315	1.71	1.22
39	Carbonates, limed; 1 soda, ¼ potash	306	3.00	1.29
	Carrot, Tops, 1901.			
48	Carbonates, limed; ¼ soda, ¼ potash	....	2.17	1.53
39	Carbonates, limed; 1 soda; ¼ potash	....	4.76	1.00

The foregoing results on the whole seem to show that, as far as concerned the carrot roots, the employment of an extra three-quarter ration of sodium salt failed to materially affect either the yield or the percentages of potassium oxid in the crop, yet the percentages of sodium oxid in the crop were greatly increased in both instances.

It is of interest to observe that in the case of the tops the use of a greater amount of sodium salt in the manures was accompanied by more than double the amount of sodium oxid in the dry matter, or by a still greater increase than in the case of the roots. At the same time the percentage of potassium oxid in the dry matter of the tops was materially lessened, thus indicating a decided conservation so far as the tops were concerned, which was probably sufficient to insure an economy of potash for the entire plant.

Results Secured with Radishes and Flat Turnips Raised in 1905.

It should perhaps be repeated here that in 1905 each plat received manures as follows:

Pounds per acre.
1,000 dried blood.
1,500 dissolved bone.
420 magnesium sulfate.

The full rations of potassium and sodium salts were as follows:

Pounds per acre.
354.9 potassium carbonate.
402.8 muriate of potash.
200.0 sodium chlorid (common salt).
185.0 sodium carbonate (soda ash).

Below are given the results secured with the radish in 1905:

Radish, White Strasburg, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Sodium oxid.	Per cent. in dry matter. Potassium oxid.
12	Chlorids, limed once; ¼ soda, ¼ potash	398	2.99	3.22
3	Chlorids, limed once; 1 soda, ¼ potash	456	4.08	3.17
24	Chlorids, limed thrice; ¼ soda, ¼ potash	324	3.50	2.42
15	Chlorids, limed thrice; 1 soda, ¼ potash	438	4.44	3.54
36	Carbonates, limed once; ¼ soda, ¼ potash	372	2.95	2.95
27	Carbonates, limed once; 1 soda, ¼ potash	400	4.11	2.58
48	Carbonates, limed thrice; ¼ soda, ¼ potash	375	2.90	3.21
39	Carbonates, limed thrice; 1 soda, ¼ potash	398	4.04	2.60
11	Chlorids, limed once; ¾ soda, ¾ potash	557	2.99	6.13
1	Chlorids, limed once; 1 soda, ¾ potash	550	3.16	6.34
23	Chlorids, limed thrice; ¾ soda, ¾ potash	498	2.85	5.81
13	Chlorids, limed thrice; 1 soda, ¾ potash	547	2.66	6.54
35	Carbonates, limed once; ¾ soda, ¾ potash	553	2.74	5.03
25	Carbonates, limed once; 1 soda, ¾ potash	556	2.88	5.52
47	Carbonates, limed thrice; ¾ soda, ¾ potash	514	2.75	5.11
37	Carbonates, limed thrice; 1 soda, ¾ potash	555	2.75	5.43

The addition of a three-quarter ration of sodium salt in all four cases where a quarter ration each of the sodium and potassium salt had already been applied was followed by increased crops. The gains amounted to 14.5, 35.2, 7.5, and 6.1 per cent; the greatest gain having occurred where the chlorids were used upon the land which had already been limed three times. In all four cases the percentage of sodium oxid in the dry matter of the roots was greatly increased when the additional sodium salt was employed in the manures. In one case the percentage of potassium oxid was slightly less, in one case it was about 1 per cent. greater, and in the other two cases it was decidedly less where the extra sodium salt was used. The case of plats Nos. 15 and 24 furnishes a striking exception to the general results and also to those secured in 1899, for the employment of an additional amount of sodium salt was followed in this case by a greater percentage of potassium oxid in the crop.

In all cases where the percentages of potassium oxid were less, in accompaniment with the higher percentages of sodium oxid in the crop and the greater yield, an economy of the potassium had been brought about.

Supplementing the three-quarter rations of the two salts by an extra quarter ration of sodium salt was followed in one case by a decreased yield, too small to have significance, and in three cases by somewhat increased yields, two of which were of sufficient magnitude to be possibly significant. In one of these instances the percentage of sodium oxid was unchanged, in another it was less, and in two other cases it was slightly greater, where the extra sodium salt was added. In all four cases the percentages of potassium oxid in the roots were materially increased where the extra sodium salt had been added to the manures, and yet certainly in some, if not all, cases, without a corresponding advantage to the crop. Taking these results in immediate comparison with those where the initial supply of potassium in the manures was less, it appears (excepting in one of the latter instances) that there was a greater economy of the potassium supply induced by the sodium when the supply of potassium

in the manures was limited. Nevertheless, a positive waste of the potassium in the manures occurred when the supply was great. In the latter case the amount of potassium oxid in the dry matter of the plant appears to have probably been in excess of the physiological necessities.

Below is shown the result of adding a half, and in some cases a full ration of sodium salt to the full ration of potassium salt:

Radish, White Strasburg, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Sodium oxid.	Per cent. in dry matter. Potassium oxid.
10	Chlorids, limed once; 0 soda, 1 potash	522	1.94	6.62
8	Chlorids, limed once; ½ soda, 1 potash	542	2.34	7.72
5	Chlorids, limed once; 1 soda, 1 potash	574	2.73	6.75
22	Chlorids, limed thrice; 0 soda, 1 potash	522	2.02	6.86
20	Chlorids, limed thrice; ½ soda, 1 potash	553	2.66	6.67
34	Carbonates, limed once; 0 soda, 1 potash	548	1.71	6.33
32	Carbonates, limed once; ½ soda, 1 potash	555	2.24	6.19
46	Carbonates, limed thrice; 0 soda, 1 potash	508	2.27	6.05
41	Carbonates, limed thrice; 1 soda, 1 potash	532	2.64	5.32

In every instance the yields were greater where the full ration of potassium salt was supplemented by a half and a full ration of sodium salt. The effect of adding the sodium salt in the manures was in every case to increase the percentage of sodium oxid in the crop in a marked degree. In one of the four cases the percentage of potassium oxid in the crop was increased, and in the other three cases lessened, upon applying the sodium salt. The remarkable results in the case of plats 8 and 10 are in the same direction as those in the case of plats Nos. 15 and 24 (page 247). These results were so exceptional that the analytical work was verified by additional determina-

tions in both cases, yet nevertheless a suspicion might have remained that the samples had been interchanged were it not for the fact that the percentages of sodium determined in the same solutions were in both cases in full agreement with what was to have been expected had no such interchange resulted. Therefore the results indicate that the peculiarities were due to some unknown and obscure factor or factors, rather than to an interchange of samples or to analytical errors.

Turnip, Flat, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
12	Chlorids, limed once; ¼ soda, ¼ potash	240	2.14	2.07
3	Chlorids, limed once; 1 soda, ¼ potash	373	3.09	1.99
24	Chlorids, limed thrice; ¼ soda, ¼ potash	192	2.94	1.79
15	Chlorids, limed thrice; 1 soda, ¼ potash	294	3.59	1.96
36	Carbonates, limed once; ¼ soda, ¼ potash	227	2.45	1.92
27	Carbonates, limed once; 1 soda, ¼ potash	269	3.46	1.68
48	Carbonates, limed thrice; ¼ soda, ¼ potash	246	2.47	2.03
39	Carbonates, limed thrice; 1 soda, ¼ potash	372	2.13	2.94
6	Chlorids, limed once; ½ soda, ½ potash	390	1.91	2.60
2	Chlorids, limed once; 1 soda, ½ potash	402	2.42	3.05
18	Chlorids, limed thrice; ½ soda, ½ potash	340	2.30	2.48
14	Chlorids, limed thrice; 1 soda, ½ potash	377	2.49	2.72
30	Carbonates, limed once; ½ soda, ½ potash	311	2.12	2.29
26	Carbonates, limed once; 1 soda, ½ potash	385	2.39	2.48
23	Chlorids, limed thrice; ¾ soda, ¾ potash	376	2.09	3.33
13	Chlorids, limed thrice; 1 soda, ¾ potash	371	1.70	3.15
47	Carbonates, limed thrice; ¾ soda, ¾ potash	404	1.72	3.25
37	Carbonates, limed thrice; 1 soda, ¾ potash	392	1.90	3.22

Turnip, Flat, Roots, 1905.—Concluded.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
22	Chlorids, limed once; 0 soda, 1 potash	369	1.23	3.69
20	Chlorids, limed once; ½ soda, 1 potash	392	1.38	3.94
17	Chlorids, limed once; 1 soda, 1 potash	382	1.71	3.82
34	Carbonates, limed once; 0 soda, 1 potash	414	1.26	3.53
32	Carbonates, limed once; ½ soda, 1 potash	420	1.47	3.53
29	Carbonates, limed once; 1 soda, 1 potash	358	1.66	3.45
46	Carbonates, limed thrice; 0 soda, 1 potash	384	1.27	3.49
44	Carbonates, limed thrice; ½ soda, 1 potash	399	1.38	3.88
41	Carbonates, limed thrice; 1 soda, 1 potash	394	1.75	3.50

When a quarter ration each of the two salts was supplemented by an additional three-quarter ration of sodium salt, the increase in yield in the four cases amounted to 55, 53, 19, and 51 per cent. In three of the four cases the percentage of sodium oxid in the dry matter of the roots was decidedly increased upon the application of an additional amount of sodium salt in the manures.

In the first and third instances the percentage of potassium oxid in the dry roots was less, and in the second and fourth instances it was greater, where the extra sodium oxid was employed in the manures. These results indicate a conservation of potash, only when the smaller amount of lime was applied.

In the three cases where a half ration of each of the two salts was supplemented by the addition of a half ration of sodium salt the yields all showed an increase, though in one instance it amounted to but about three per cent., or too little to be significant. In all cases the percentages of sodium oxid and of potassium oxid in the dry matter of the roots were increased where the extra sodium salt was applied in the manures. On account of the increase of the potas-

sium percentage accompanying the increase of crop, there would seem to be ground for concluding that the extra potassium might have been the cause of the increase, were it not for the fact that in the case of the crop of plat No. 3 the percentage of potassium oxid was but 1.99, and yet the yield was 373 pounds, or more than in the case of plat No. 18 where the potassium oxid in the dry matter amounted to 2.48 per cent. At all events, in this instance no satisfactory evidence was afforded to show that the presence of the extra sodium salt resulted in effecting an economy of the potassium, at least in so far as concerned the roots.

The addition of an extra quarter ration of the sodium salt to the three-quarter ration of the two salts failed in both cases to increase the crop. In one instance the percentage of sodium oxid in the crop was less and in another greater, and the percentages of potassium oxid in both cases were slightly less, where the extra quarter ration of sodium salt was employed.

The most effective light upon the ability of the sodium salt to conserve the potassium, where the supply of the latter is large, is furnished when full rations of the respective potassium salts were supplemented by half and full rations of the respective sodium salts. These tests in two of the three series indicate slight possible benefit, as concerns yield, in consequence of the presence of the extra sodium salt. In the third series of tests there was one marked exception to this apparent gain. In all three series there was unmistakable evidence of an increased percentage of sodium oxid in the roots where the extra sodium salt was present in the manures. The results as concerns the potassium oxid in the roots were widely variable, but on the whole they give no positive evidence of a conservation of the potassium salt in consequence of the presence of the extra sodium salt.

ADDITIONAL DATA BEARING UPON THE ECONOMICAL UTILIZATION OF PHOSPHORIC ACID, POTASSIUM, AND OTHER SUBSTANCES BY PLANTS AS INFLUENCED BY SODIUM SALTS.

In some instances noted in this chapter the amount of available potassium present was in excess of the needs of the plants, a condition which would exercise a very considerable influence upon the extent of its conservation and upon the relative yields from the plats which are compared. The economic discussions contained herein should only be considered with this fact in mind.

It is of interest to compare the analyses of certain of the crops of white Strasburg radish grown in 1899. Below are the data:

	Plat No. 14. Soda, 1, Potash, ½.	Plat No. 22. Soda, 0, Potash, 1.
Yield (in pounds)	766	709
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	0.90	0.78
Potassium oxid	5.19	8.43
Sodium oxid	5.12	2.02
Calcium oxid	1.32	1.46
Magnesium oxid,	0.63	0.89

From the foregoing it will be seen that when the full ration of potassium salt was used, which amount was in excess of the plant needs, the yield was actually less than when a half ration of potassium supplemented by a full ration of sodium was employed. It will be observed that the percentage of phosphoric acid was greater in the latter than in the former case, but that the amounts of potassium oxid, calcium oxid, and magnesium oxid per hundred pounds of dry matter were all greater when the full ration of potassium was applied. A much greater amount of sodium oxid was, however, removed where the sodium salt was added in the manures. The extra loss of sodium oxid from the removal of the crop was, however, but 3.10 pounds per hundred pounds of dry matter when the sodium was present in the manures, while on the other hand the loss of potassium oxid was 3.24 pounds for every hundred pounds of dry matter

in the case where the sodium salt was omitted from the manures. In view of the sodium costing practically nothing if bought in nitrate of soda, kainit, and muriate of potash, the saving in potassium from its use was far more than enough to offset the losses in other ingredients.

If it should be shown that the value of the product for nutrient purposes is greater when the per cent. of phosphorus is increased, the economy resulting from the presence of the sodium salt would then be found to be still more enhanced.

It should be observed that the liming having been identical and chlorids having been applied in the case of both of the plats cited above, the results in that respect are strictly comparable.

A comparison similar to the one given above is rendered possible by data from the same crop and year in the limed carbonate series.

Below are the data to which reference is made:

	Plat No. 38. Soda, 1, Potash, ½.	Plat No. 46. Soda, 0, Potash, 1.
Yield (in pounds)	662	655
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	1.10	0.96
Potassium oxid	5.27	9.82
Sodium oxid	5.72	1.43
Calcium oxid	1.17	1.61
Magnesium oxid	0.67	1.10

The amounts of phosphoric acid and of sodium oxid in the dry matter were, as before, greater when the sodium salt was employed. The additional sodium oxid removed per hundred pounds of dry matter, when the sodium salt was added to the manures, amounted to 4.29 pounds, and the similar loss of extra potassium oxid when the full ration of potassium salt was used without supplemental sodium salt amounted to 4.55 pounds. This is sufficient to show in this case that the sodium salt even at current prices would have effected an economy so far as concerned the conservation of plant food removed by the radish roots, and when it is borne in mind that

the sodium could have been secured in nitrate of soda or in certain of the German potash salts practically free of cost, the bearing of this feature of these results becomes even more significant.

Below are given data secured with the flat turnip in the same year:

	Plat No. 15. Soda, 1, Potash, ¼.	Plat No. 22. Soda, 0, Potash, 1.
Yield (in pounds)	293	234
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	1.26	1.03
Potassium oxid	2.13	4.54
Sodium oxid	5.05	1.46
Calcium oxid	1.26	1.31
Magnesium oxid	0.69	0.62

In this instance the yield was greater when the quarter ration of potassium salt was supplemented by a full ration of sodium salt than when a full ration of potassium salt was used without any sodium salt whatsoever.

It will be seen that, as in the case of the radish, the use of the sodium salt raised the percentages of sodium oxid and of phosphoric acid in the dry matter of the roots, but, unlike the previous instances, the use of the sodium salt slightly increased rather than lessened the magnesium oxid removed.

The extra amount of sodium oxid removed per hundred pounds of dry matter when the sodium salt was added in the manures, amounted to 3.59 pounds; and the extra quantity of potassium oxid removed per hundred pounds of dry matter when the sodium salt was omitted and a full ration of potassium salt was used in the manures, amounted to 2.41 pounds. The conservation of the potassium salt by virtue of employing the sodium salt was great, though not so striking as in the case of the radish.

The following are results with the Norbiton Giant beet (mangel-wurzel):

	Plat No. 15. Soda, 1, Potash, ½.	Plat No. 22 Soda, 0, Potash, 1.
Yield (in pounds)	682	689
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	0.32	0.33
Potassium oxid	0.84	3.65
Sodium oxid	4.63	1.71
Calcium oxid	0.26	0.26
Magnesium oxid	0.50	0.51

In this case the percentages of phosphoric acid, calcium oxid, and magnesium oxid are practically the same.

When the sodium salt was used the extra quantity of sodium oxid removed in the roots amounted to 2.92 pounds per hundred of dry matter, and when the full ration of potassium salt was employed without the sodium salt the extra amount of potassium removed per hundred of dry matter was 2.81 pounds.

Still another comparison of results with the same beet is possible in the limed carbonate series. The results are as follows:

	Plat No. 39. Soda, 1, Potash, ½.	Plat No. 46. Soda, 0, Potash, 1.
Yield (in pounds)	601	797
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	0.39	0.35
Potassium oxid	0.81	3.69
Sodium oxid	5.10	1.06
Calcium oxid	0.29	0.27
Magnesium oxid	0.48	0.47

This is the first instance discussed in this particular connection in which the yield has been decidedly greater where the full ration of potassium was employed without any supplementary sodium salt. It will be seen that far less potassium oxid was removed in the crop when the sodium salt was applied in the manures but the lessened yield may have been enough to fully offset this apparent saving.

It is of interest to observe that the sodium salt applied in the manures did not materially change the percentages of phosphoric acid, calcium oxid, and magnesium oxid.

Below are the data secured with chicory, in the limed chlorid series (crop of 1899):

	Plat No. 15. Soda, 1, Potash, ¼.	Plat No. 22. Soda, 0, Potash, 1.
Yield (in pounds)	189	312
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	0.48	0.45
Potassium oxid	0.62	1.42
Sodium oxid	1.01	0.37
Calcium oxid	0.24	0.22
Magnesium oxid	0.25	0.18

In this case the substitution of a full ration of sodium salt for a three-quarter ration of potassium salt resulted in a smaller yield and in an increase of sodium oxid in the dry matter from 0.37 to 1.01 per cent. At the same time there was an increase in the percentages of phosphoric acid, calcium oxid, and magnesium oxid. The percentage of potassium oxid, on the contrary, was depressed from 1.42 to 0.62. In this case, as in that of the last-mentioned results with beets, the depression of the yield probably far more than offsets the conservation of the potassium in the soil.

Still another comparison is rendered possible with chicory roots in the same year, in the limed carbonate series. The results are given below:

	Plat No. 39. Soda, 1, Potash, ¼.	Plat No. 46. Soda, 0, Potash, 1.
Yield (in pounds)	205	256
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	0.59	0.46
Potassium oxid	0.37	1.43
Sodium oxid	1.04	0.35
Calcium oxid	0.26	0.24
Magnesium oxid	0.32	0.18

In this instance, as in the preceding one, cutting down the potassium salt to a quarter ration and adding in its place a full ration of the sodium salt raised the percentages in dry matter of all of the in-

gredients excepting potassium oxid, which was depressed from 1.43 to 0.37 per cent. In view of the reduction in yield and the increased drain on the other mineral elements, it does not seem to have been an advantageous proceeding to substitute the sodium salt for the potassium salt in the manures, even notwithstanding that less potassium oxid was withdrawn from the soil in each one hundred pounds of dry roots.

The results secured with the flat turnip roots in 1905 render possible certain comparisons which throw light upon the conservation of potassium in consequence of using sodium salts in the manures. All of the results used in this comparison were from the chlorid series which had been limed once. The results are as follows:

	Plat No. 2. Soda, 1, Potash, ½.	Plat No. 6. Soda, ½, Potash, ½.	Plat No. 10. Soda, 0, Potash, 1.
Yield (in pounds)	402	390	417
In Dry Matter.	*Per cent.*	*Per cent.*	*Per cent.*
Nitrogen	2.80	2.41	2.37
Phosphoric acid	1.42	1.29	1.33
Potassium oxid	3.05	2.60	3.93
Sodium oxid	2.42	1.91	1.04
Calcium oxid	0.80	0.83	0.80
Magnesium oxid	0.35	0.37	0.47

In this case the yields were but slightly less where a half ration of each salt was used and where a half ration of potassium salt was supplemented by a full ration of sodium salt, than where the full ration of potassium salt was employed.

In the instance of a half ration of each (plat No. 6) a depression of the magnesium oxid, phosphoric acid, and potassium oxid resulted. The percentage in the dry matter dropped in the latter case from 3.93 to 2.60. When a further half ration of sodium salt was added (plat No. 2), even more nitrogen was removed than in either of the other cases and the conservation of the potassium was less than before, which factor, added to the cost of the additional half ration of sodium salt, also leaves one disinclined to believe that any actual net benefit resulted from its addition. It is of course possible in the last instance

that the excess of nitrogen may have been changed into proteid or amide combinations and hence may have represented a gain in the feeding value of the crop, but it is just as likely that the excess of nitrogen may have been present in the crop as nitrate, considerable of which was usually found in the turnip, and if so its removal by the crop may have been positively disadvantageous.

Additional light upon the possible conservation of potassium by sodium salts as shown by the tops is afforded by certain analyses of the tops of flat turnips grown in the year 1905 in the chlorid series which had been limed three times. These results are as follows:

		Plat No. 14. Soda, 1, Potash, ½.	Plat No. 22. Soda, 0, Potash, 1.
Yield (in pounds)	Tops	647	640
	Roots	377	369
In Dry Matter.		*Per cent.*	*Per cent.*
Nitrogen		3.28	3.25
Phosphoric acid		1.31	1.33
Potassium oxid		2.28	3.28
Sodium oxid		2.44	1.45
Calcium oxid		5.29	4.98
Magnesium oxid		1.04	1.58

The only material change in the composition of the dry matter was a depression of the magnesium and potassium oxids upon substituting a full ration of sodium salt for the half ration of potassium salt. There was no sacrifice of crop in this case, and there resulted a saving of one pound of potassium oxid, per hundred pounds of dry matter, in the amount removed by the turnip tops. It is a source of regret that no facilities were afforded for examining the drainage water in order to see if the potash which failed to pass into the crop was lost in the drainage water. At all events it should be pointed out that it has been shown in earlier experiments at this Station* that when sodium salts were applied for a series of years, after which neither sodium nor potassium salts were used, the crops seemed to

*Bulletin No. 106, May, 1905, pp. 138–153.

do better where previous generous rations of potassium salt had been supplemented by sodium salt than when the former were used alone. This may not necessarily indicate a conservation of potassium in the soil, for some other may be the true explanation of the results; yet had the use of the sodium salt caused a serious loss of potassium salt in the drainage water, it would have been expected to have shown itself by a lessening of the yield.

An analysis of the roots of the flat turnip from the thrice-limed carbonate series (plat No. 42) which has not been presented previously, admits of some interesting comparisons with the analyses of other turnips in the same series. The results are given below:

	Plat No. 39.	Plat No. 48.	Plat No. 42.	Plat No. 47.
Soda ration.	1	¼	½	¾
Potash "	¼	¼	½	¾
Yield (in pounds)....	372	246	343	404
In Dry Matter.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Nitrogen............	2.67	3.28	2.70	2.60
Phosphoric acid......	1.39	1.30	1.38	1.41
Potassium oxid......	2.94	2.03	2.62	3.25
Sodium oxid.........	2.13	2.47	2.04	1.72
Calcium oxid........	0.89	1.15	0.90	0.88
Magnesium oxid......	0.39	0.41	0.40	0.37

It will be seen that the yield from a quarter ration each of the sodium and potassium salt amounted to but 246 pounds. With the extra addition of a three-quarter ration of sodium salt a larger crop was secured than with a half ration of each, though it was smaller than that produced when a three-quarter ration of each salt was applied. Comparing the results from plats Nos. 39 and 42, it will be seen that the extra half ration of sodium salt applied in the manures in the former case was followed by only a slight increase in the sodium oxid in the dry matter and by an increase rather than a depression of the potassium oxid. From this it would appear that some of the benefit derived from applying the sodium salt may have been due to its liberation of potassium. A similar conclusion seems to be necessitated also when one compares the percentages in the crops from plats Nos. 39 and 48.

In the case of certain crops there have been suggestions that there may be a greater conservation of potassium in consequence of applying sodium salts when the season is dry and the chances for the replacement of potash by soda in the soil are probably less favorable.

Still another comparison of certain results not previously presented is afforded by the crop from plat No. 25 in the carbonate series to which lime had been applied once. The data are given below:

	Plat No. 25. Soda, 1, Potash, $\frac{3}{4}$.	Plat No. 34. Soda, 0, Potash, 1.
Yield (in pounds)	389	414
In Dry Matter.	*Per cent.*	*Per cent.*
Nitrogen	2.61	2.53
Phosphoric acid	1.46	1.40
Potassium oxid	2.80	3.53
Sodium oxid	1.99	1.26
Calcium oxid	0.84	0.78
Magnesium oxid	0.38	0.46

With the introduction of the sodium salt in this instance the percentage of sodium oxid in the dry matter rose from 1.26 to 1.99 and the percentage of potassium oxid fell from 3.53 to 2.80 per cent. With this decrease the percentages of all of the other ingredients but magnesium oxid rose.

On the whole, the conservation of potassium by the application of the sodium salt was of doubtful advantage, even though the sodium were secured without cost.

FURTHER DATA CONCERNING THE INFLUENCE OF SODIUM AND POTASSIUM SALTS UPON THE PERCENTAGES OF PHOSPHORIC ACID AND OF BASES IN THE DRY MATTER OF THE PLANT.

In view of the many results given previously, showing that, in the presence of small supplies of potassium salts, sodium salts materially increased the percentages of phosphoric acid in the dry matter of the plant, it was desired to ascertain how marked the results would be if

no potassium salt was applied in the manures. These results are given below:

White Strasburg Radish, Roots, 1905.

	Plat No. 4. Soda, 1, Potash, 0.	Plat No. 10. Soda, 0, Potash, 1.
Yield (in pounds)	274	522
In Dry Matter.	*Per cent.*	*Per cent.*
Nitrogen	4.66	3.51
Phosphoric acid	1.24	1.08
Potassium oxid	1.95	6.62
Sodium oxid	5.43	1.94
Calcium oxid	1.55	1.12
Magnesium oxid	1.03	0.83

It will be observed that the percentage of phosphoric acid in the dry matter where the full ration of potassium salt was applied was 1.08, and that where the full ration of sodium salt was used without any addition of potassium salt the percentage of phosphoric acid in the dry matter of the roots rose to 1.24. This matter is chiefly of interest in case it were desired to secure plants rich in phosphorus. Whether or not there would be any object in this would doubtless depend upon whether the extra phosphorus is really present in organic or inorganic combinations, a point not yet investigated. It is incidentally of interest to note that when the full ration of sodium salt was employed the removal of nitrogen and of all of the mineral elements excepting potassium was far greater than when the full ration of potassium salt was employed.

Concerning the Influence of the Carbonates and Chlorids upon the Composition of the Dry Matter of the Leaf of the Radish, and of Turnip Roots.

It has already been repeatedly shown that as a general rule the use of sodium carbonate and potassium carbonate in the manures resulted in higher percentages of phosphoric acid in the dry matter of the roots than the use of the chlorids. On this account it was de-

sired to see if similar indications would be afforded by the tops. In order to render the results comparable the tops from plats Nos. 13 and 37 were selected, for the reason that both plats had been limed in an identical manner and because the yields were nearly the same; for example, the yields of tops and roots in the former case were 520 and 547 pounds, respectively, and in the latter case 527 and 572 pounds, for like areas.

Below are given the results of the analysis of the radish tops from the two plats each of which received a full ration of sodium salt and also a three-quarter ration of potassium salt:

Radish Tops.

In Dry Matter.	Plat No. 13. Chlorids. *Per cent.*	Plat No. 37. Carbonates. *Per cent.*
Nitrogen	4.69	4.93
Phosphoric acid	1.17	1.26
Potassium oxid	3.98	3.07
Sodium oxid	2.99	2.62
Calcium oxid	4.77	4.09
Magnesium oxid	0.95	0.78

It will be seen that the tops in this case follow the same general rule which has been observed for the roots, or in other words the percentage of phosphoric acid in the dry matter was greater where the carbonates were applied as manures than where the chlorids were used. Whether this is due to a greater solvent action of the carbonates upon the phosphorus compounds of the soil or whether the same would be found to be true of plants grown in solution is a point which it is hoped may be determined by later experiments. In this case the nitrogen increase was coincident with the increase of phosphoric acid, though it will be noticed that a smaller amount of all of the bases was present in the dry matter of the plants manured with the carbonates than in those manured with the chlorids. Whether this was due directly to the manures or to the somewhat better development of the crop in the former instance, as indicated by the yields mentioned above, remains to be ascertained.

Similar comparisons not previously made are possible between the flat turnip roots upon plats Nos. 1 and 25. Both plats had been limed once, and each received a full ration of sodium salt and a three-quarter ration of potassium salt. In the former instance chlorids were used and in the latter the carbonates. The respective yields upon like areas were 379 and 389 pounds. Below are given the analytical results:

In Dry Matter.	Plat No. 1. Chlorids. *Per cent.*	Plat No. 25. Carbonates. *Per cent.*
Nitrogen	2.72	2.61
Phosphoric acid	1.28	1.46
Potassium oxid	3.87	2.80
Sodium oxid	1.97	1.99
Calcium oxid	0.95	0.84
Magnesium oxid	0.34	0.38

In this instance, just as in the case of the radish tops, the use of the carbonates was followed by a higher percentage of phosphorus in the dry matter than the use of the chlorids; the same was true also of the magnesium oxid. The sodium oxid was practically identical in both cases. The calcium oxid was less where the carbonates were used, and the potassium oxid was decidedly less, just as they were in the case of the radish tops.

Pot Experiments with Sodium Salts in 1898.

The experiments to be described here were conducted in pots of the Wiley pattern. These were filled with surface (agricultural) soil from the unmanured permanent experimental plats of the Station, Nos. 72, 74, 76, 78, 80, 82, and 84. Seventy-two and one-half pounds of the soil were placed in each pot. The moisture content was determined, and also the water capacity of the soil, so that by frequent weighings proper amounts of water could be maintained therein. Each of the forty-nine pots received the following amounts of manurial substances:

Grams per pot
2.2900 magnesium sulfate c. p.
12.2081 dissolved bone-black.
47.0475 air-slaked lime (three tons per acre).
6.9000 ammonium nitrate c. p.

The dissolved bone-black furnished 2.3 grams of phosphoric acid per pot.

Concerning the ammonium nitrate, it was applied in portions of 2.3 grams each, on May 25, July 2, and August 12. Each portion was dissolved in 20 c.c. of water and applied just before the plants were watered.

The *full ration* of potassium oxid amounted to 1.6355 grams per pot, and the *full ration* of sodium oxid to 1.6355 grams. To supply these amounts there were required per pot 3.0253 grams of *dry* c. p. potassium sulfate and 3.7441 grams of *dry* c. p. sodium sulfate. The sodium sulfate contained 0.15 per cent. of water, hence 3.7495 grams per pot of the undried material were used.

The amount of potash employed was equal to 360 pounds per acre of potassium carbonate, containing 57.94 per cent. of potassium oxid. This was the same amount of that salt which had been used in certain of the field experiments described previously, and for that reason it was made the basis of manuring in this case. Seven series of pots were employed in the experiment. Four in each series were devoted to common spinach, and three to barley. The larger number of pots was used for spinach on account of the fact that only a few plants could be grown per pot, and hence any influence due to individuality would be less, the greater the number of pots employed. Both kinds of seed were planted on May 24.

On June 2 the barley plants were thinned to sixty per pot, and on June 9 the spinach plants were thinned to nine per pot.

The spinach was harvested, photographed, and weighed, green, on July 11. Later the spinach was dried artificially to essentially constant weight. The weight of the total crop in each series was unfortunately recorded instead of the weight of the crop from each pot.

The barley was harvested July 28, before the grain was fully mature. The weight of crop from each pot was taken at once, and later the material was dried artificially, as in the case of the spinach.

On July 15 the pots in which common spinach had been grown were planted with New Zealand spinach, and on August 2 these plants were thinned to five per pot. One plant in pot No. 31 died August 15, and also one in pot No. 45, on August 20. Two of the spinach pots, viz., Nos. 40 and 41, were accidentally overturned on September 2, as a result of which the plants were somewhat disturbed and some of the soil in the pots, was lost. The lost soil was at once replaced by more of the same kind as was employed originally. The New Zealand spinach was harvested October 8, the weight of crop from each pot being taken separately. Later the material was dried artificially to practically constant weight.

The pots which were devoted to barley as a first crop were planted the second time on July 29 with seed of golden millet. On September 3 the plants were finally thinned to seventy-six per pot. The crop was harvested on October 17. The weights of the crops given below represent the material which had been dried to practically constant weight by artificial means.

Below follow successively the results with the four crops:

Results with Common Spinach, Inclusive of Roots.

Series No.	Pot Nos.	Rations of Sodium and Potassium Salts.	Grams of Dry Matter. (Average per pot.)
1	31–34	Potassium, full ration, Sodium, $\frac{4}{3}$ ration.	13.5
2	38–41	Potassium, $\frac{2}{3}$ ration, Sodium, $\frac{2}{3}$ ration, ...	10.7
3	45–48	Potassium, $\frac{1}{3}$ ration, Sodium, $\frac{2}{3}$ ration.	11.1

Results with Common Spinach.—Concluded.

Series No.	Pot Nos.	Rations of Sodium and Potassium Salts.	Grams of Dry Matter. (Average per pot)
4	52–55	Potassium, ⅓ ration, Sodium, ⅓ ration.	8.6
5	59–62	Potassium, ⅓ ration, Sodium, none.	6.7
6	66–69	Potassium, ⅔ ration, Sodium, none.	7.9
7	73–76	Potassium, none, Sodium, none.	2.4

The average yield without either potassium or sodium salts was very poor, amounting to but 2.4 grams.

With the two-third ration of the potassium salt the yield was 7.9, and when the two-third ration of sodium salt was added to it the yield rose to 10.7 grams.

The one-third ration of potassium salt gave a yield 1.2 grams less than the two-third ration.

The one-third ration of potassium salt when supplemented with a one-third ration of sodium salt gave a yield of 1.9 grams greater than without the sodium salt.

The one-third ration of potassium salt gave a yield 2.5 grams greater when supplemented by a two-third ration than where supplemented by only a one-third ration of sodium salt.

In no case were the yields with abbreviated rations of potassium salts equal to that when the full ration of potassium salt was supplemented by a two-third ration of the sodium salt.

These results, taken as a whole, indicate a distinct advantage from the employment of the sodium salt, especially when the potassium salt was limited to a small amount.

Below are given the analytical data secured in connection with the crops of common spinach which have just been discussed:

Common Spinach (Including Roots). Grown in Pots in 1898.

Rations of Potassium and Sodium Salts.	$\frac{1}{3}$ Potassium, 0 Sodium.	$\frac{1}{3}$ Potassium, $\frac{1}{3}$ Sodium.	$\frac{1}{3}$ Potassium, $\frac{2}{3}$ Sodium.	$\frac{2}{3}$ Potassium 0 Sodium.	$\frac{2}{3}$ Potassium, $\frac{1}{3}$ Sodium.
Series No.	5	4	3	6	2
Pot Nos.	59–62	52–55	45–48	66–69	38–41
Average yield of dry matter per pot (grams)	6.7	8.6	11.1	7.9	10.7
Analysis of Dry Matter.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Total silica*	3.18	7.33	7.82	6.60	4.58
Carbon dioxid (CO_2)	4.31	4.77	4.32	5.10	5.21
Carbon	0.08	0.17	0.16	0.10	0.10
Crude ash*	20.67	25.65	24.62	25.08	23.80
Crude ash, less carbon and CO_2.	16.28	20.71	20.14	19.88	18.49
Potassium oxid (K_2O)	2.44	2.66	2.25	4.33	3.21
Sodium oxid (Na_2O)	1.64	2.51	3.05	0.54	2.16
Phosphoric acid (P_2O_5)	0.49	0.49	0.43	0.48	0.42

It will be seen that upon supplementing a one-third ration of potassium salt with a one-third ration of sodium salt the yield was increased, the percentage of phosphoric acid was not affected, and the percentages of both potassium and sodium oxids were increased.

When the one-third ration of potassium salt was supplemented by a two-third ration of sodium salt the per cent. of phosphoric acid was slightly less than before. The per cent. of sodium oxid was in this case nearly doubled when the sodium salt was added in the manures, and the percentage of potassium oxid in the crop was lessened. Nevertheless the crop was actually increased more than 60

*In view of the fact that special precautions had not been taken when harvesting to remove all of the silica possible, the silica and crude ash determinations are only of general interest.

per cent. It appears probable, therefore, that the failure to secure larger crops, when using only the potassium salt, was due to inability of the plants to make the best use of the potash at their disposal in the pot, and of that which they had actually removed from the soil unless a certain amount of sodium was also added.

It will have been seen from the table on page 266 that raising the supply of potassium salt from a one-third to a two-third ration was followed by only a moderate gain in crop. This fact is of added interest when one notes that a two-third ration of the potassium salt when used without the sodium salt gave a smaller yield than was obtained in either case with a one-third ration of potassium salt when the latter was supplemented by a one-third and by a two-third ration of sodium salt. A further significant feature is that a one-third ration of potassium salt when supplemented by a two-third ration of sodium salt gave a far better result than a two-third ration of potassium salt when used without the sodium salt. Still another fact emphasizing the influence of the sodium salt was the gain of over 34 per cent. in the crop when the two-third ration of potassium salt was supplemented by a two-third ration of sodium salt. Attention should also be called to the fact that the greater yield when the sodium salt was added was accompanied by a decrease in the potassium oxid of over one per cent. and of phosphoric acid of .06 per cent. This seems to militate against a conclusion that the sodium had proved helpful by virtue of serving as a carrier of phosphoric acid or as a liberator of soil potash. These data lead rather to the conclusion that the sodium performed some physiological function in the plant, since the differences are too great and the data are of such a character as to seemingly preclude that more than a slight portion of the benefit could probably have been due to any influence upon the osmotic pressure of the soil solution which the sodium salt might have exerted. Again, the claim that the sodium salt might have influenced the moisture content of the soil favorably could hardly be allowed, in view of the fact that the pots were weighed with sufficient frequency so that the water supply was maintained

within the most favorable limits. Finally, it appears unreasonable that under such ideal conditions for controlling the water supply, the beneficial results from the use of the sodium salt could be attributable to the greater carrying power of the sodium for nitric acid by virtue of the greater solubility of sodium than of potassium nitrate, as has been suggested by Lawes and Gilbert* and by Schneidewind and Müller† in connection with certain of their field experiments. In further support of this view attention is called to the fact that the nitrogen percentages which have already been discussed in connection with the crops grown in the field, failed to indicate that the advantage from using soda in those cases was apparently due to a superior carrying power of sodium for nitric acid. The only reason that nitrogen determinations were not made in this connection was that the volume of material was insufficient for the purpose after completing the other analytical work.

Attention is also called to certain earlier work at this Station‡ in connection with which the beneficial influence of the sodium was not apparently accounted for by the sodium nitrate being more soluble than the potassium nitrate and hence proving an especially useful carrier of nitrogen.

Results with Barley.

The following table shows the yields of barley in each of the seven series, and the average yield for each series:

*Phil. Trans. of Roy. Soc. of London; Series B., Vol. 192, pp. 186 and 190.

†Jour. f. Landw. 44 (1896), p. 10; Ibid. 46 (1898), pp. 2–7.

‡Sixteenth An. Rpt. R. I. Agr. Expt. Sta. (1902–1903), pp. 263–265.

Series No.	Pot No.	Rations of Potassium and Sodium Salts.	Grams of Dry Matter Produced.	Average Yield of Dry Matter per Pot. (Grams).
1	35 36 37	Potassium, full ration Sodium, ⅔ ration	38.95 34.91 38.88	37.6
2	42 43 44	Potassium, ⅔ ration Sodium, ⅔ ration	39.85 17.81* 41.04	40.5
3	49 50 51	Potassium, ⅓ ration Sodium, ⅔ ration	36.26 28.31 38.85	34.5
4	56 57 58	Potassium, ⅓ ration Sodium, ⅓ ration	35.89 39.85 37.83	37.9
5	63 64 65	Potassium, ⅓ ration Sodium, none	31.28 34.39 31.64	32.4
6	70 71 72	Potassium, ⅔ ration Sodium, none	35.05 56.80 37.59	43.2
7	77 78 79	Potassium, none Sodium, none	17.29 9.97 19.32	15.5

*This result was for some reason abnormally low, and hence it was omitted from the average.

It will be seen that the average yield without potassium or sodium salts was but 15.5 grams, and that the addition of a one-third and two-third ration raised the yield to 32.4 and 43.2 grams, respectively.

The employment of a one-third ration of sodium salt in addition to a one-third ration of potassium salt resulted in a gain of 5.5 grams, but the addition of a further one-third ration of sodium salt was followed by no increase in the yield.

A two-third ration each of sodium and potassium salt gave no

larger yield than the two-third ration of the potassium salt when the latter was employed alone.

The full ration of potassium salt used with a two-third ration of sodium salt gave a smaller average yield than a two-third ration of both, but this may have no significance owing to the variation in the yields from individual pots.

The evidence afforded by these results is to the effect that a one-third ration of potassium salt was not enough for the needs of the plants, but that a two-third ration was probably ample. Some evidence was afforded that a two-third ration of sodium salt used with a one-third ration of potassium salt was beneficial. A still more positive benefit resulted from adding only a one-third ration of sodium salt to the one-third ration of potassium salt; or in other words, the sodium salt seemed to be helpful where the supply of potassium salt was quite limited.

At this point a consideration of the analytical data obtained in connection with the barley may be of interest. In order to secure a basis for judging whether the analyses of individual crops within a given series would show as great differences as those between different series, analyses were made of the crop from every pot in two different series. These individual results and the averages for each series are given below:

Barley Plants (Aerial Portion), Grown in Pots in 1898.

Ration.	⅓ Ration Potassium. No Sodium.				⅓ Ration Potassium. ⅓ Ration Sodium.			
Series and Pot Nos.	Series 5. Pot Nos. 63–65.				Series 4. Pot. Nos. 56–58.			
Yield in grams of dry matter per pot................	31.28	34.39	31.64	Av. 32.4	35.89	39.85	37.83	Av. 37.9
	Per cent. in dry matter.	Per cent. in dry matter.	Per cent. in dry matter.	Average.	Per cent. in dry matter.	Per cent. in dry matter.	Per cent. in dry matter.	Average.
Total silica..................	1.58	1.51	1.42	1.50	1.38	1.39	1.34	1.37
Carbon dioxid (CO_2)........	0.45	0.49	0.32	0.42	0.49	0.42	0.38	0.43
Carbon.....................	0.09	0.08	0.07	0.08	0.08	0.07	0.07	0.07
Crude ash..................	7.31	7.08	6.40	6.93	7.21	6.62	6.83	6.89
Crude ash, less carbon and CO_2	6.76	6.50	6.00	6.42	6.64	6.13	6.37	6.38
Potassium oxid (K_2O).......	1.71	1.59	1.64	1.65	1.67	1.51	1.56	1.58
Sodium oxid (Na_2O)........	0.19	0.15	0.18	0.17	0.39	0.35	0.36	0.37
Nitrogen....................	2.50	2.49	2.53	2.51	2.63	2.36	2.33	2.44

So far as the sodium oxid is concerned there can be no escape from the conclusion that the percentage was unquestionably influenced by the amounts applied in the manures. It will also be observed that the yield was greater when a one-third ration each of sodium and potassium salt was employed than when the sodium salt was omitted.

The average per cent. of potassium oxid in the dry plants was slightly less with, than without, the addition of the sodium salt, which lends no support to a conclusion that the sodium salt had been beneficial by virtue of aiding the plant to take up more potassium, even though more may have been freed in the soil.

It will be seen that the per cent. of sodium oxid in the plants had been more than doubled where the extra sodium salt had been applied.

The amount of material was so small that after completing the other determinations too little remained to permit of determinations

of phosphoric acid, hence the influence of the sodium salt upon the phosphorus content of the plants could not be ascertained. From the investigations in this line in connection with the field crops (pp. 194–214) it will be recalled that the use of sodium chlorid, and even more strikingly of sodium carbonate, resulted in most cases in an increase in the percentage of phosphorus; though the nature of the results was such that this increase seemed to be probably coincident with, rather than a cause of, the gain in crop.

In this particular instance the nitrogen percentages, as a whole, are such that they lend no support to the idea that the sodium salt may have increased the yield by virtue of soda having proved superior to potash as a carrier of nitric acid to the plant. The results on the whole are unlike those obtained with the common spinach, which seemed to show unmistakable benefit from soda in some physiological capacity.

Results with New Zealand Spinach.

The table given below shows the individual and the average yields of New Zealand spinach in each of the seven series:

Series No.	Pot No.	Rations of Potassium and Sodium Salts.	Grams of Dry Matter Produced.	Average Yield of Dry Matter per Pot. (Grams).
1	31 32 33 34	Potassium, full ration Sodium, ⅔ ration	33.0 32.0 32.7 29.3	31.7
2	38 39 40 41	Potassium, ⅔ ration Sodium, ⅔ ration	*5.6 27.3 †8.0 †3.9	27.3
3	45 46 47 48	Potassium, ⅓ ration Sodium, ⅔ ration	24.1 29.4 27.8 35.2	29.1

*Probably injured at the same time that pots 40 and 41 were overturned. Omitted from average.

†Overturned by accident, and injured. Omitted from average.

Results with New Zealand Spinach.—Concluded.

Series No.	Pot No.	Rations of Potassium and Sodium Salts.	Grams of Dry Matter Produced.	Average Yield of Dry Matter per Pot. (Grams.)
4	52	Potassium, $\frac{1}{3}$ ration; Sodium, $\frac{1}{3}$ ration	30.5	29.4
	53		27.6	
	54		32.0	
	55		27.7	
5	59	Potassium, $\frac{1}{3}$ ration; Sodium, none	23.1	25.1
	60		24.5	
	61		28.3	
	62		24.5	
6	66	Potassium, $\frac{2}{3}$ ration; Sodium, none	26.4	28.0
	67		25.4	
	68		29.5	
	69		30.7	
7	73	Potassium, none; Sodium, none	21.6	22.6
	74		23.2	
	75		23.6	
	76		21.9	

It will be seen that relatively better results were secured with New Zealand spinach without the aid of potassic manures than with either common spinach or barley. This may have been due to the low feeding power of common spinach for potash, previously pointed out at this Station, a factor possibly affecting the barley in a similar way.

The use of a one-third ration of the potassium salt increased the average crop, but not to as great an extent as a two-third ration.

By the employment of a one-third ration of sodium salt in addition to the one-third ration of potassium salt a slight gain in crop apparently resulted, but the addition of a further one-third ration of sodium salt was not shown to be advantageous. The single result where a two-third ration of each salt was used is not worthy of consideration.

A slightly better average result was secured with a full than with

a one-third ration of potassium salt when it was supplemented in both cases by a two-third ration of sodium salt.

In the absence of analytical data little evidence is afforded whether the benefit from the sodium in the presence of small amounts of potassium was due to a liberation of potassium or to other causes.

Results with Golden Millet.

Series No.	Pot No.	Rations of Potassium and Sodium Salts.	Grams of Dry Matter Produced.	Average Yield of Dry Matter per pot. (Grams.)
1	35 36 37	Potassium, full ration Sodium, ⅔ ration	35.2 42.0 40.2	39.1
2	42 43 44	Potassium, ⅔ ration Sodium, ⅔ ration	29.0 32.7 40.4	34.0
3	49 50 51	Potassium, ⅓ ration Sodium, ⅔ ration	29.9 31.4 36.6	32.6
4	56 57 58	Potassium, ⅓ ration Sodium, ⅓ ration	33.1 33.9 34.9	34.0
5	63 64 65	Potassium, ⅓ ration Sodium, none	33.2 37.0 27.7	32.6
6	70 71 72	Potassium, ⅔ ration Sodium, none	47.4 46.8 42.3	45.5
7	77 78 79	Potassium, none Sodium, none	23.4 20.4 22.0	21.9

It appears from the foregoing table that the average yield without the use of sodium and potassium salts was 21.9 grams; with a one-

third ration of potassium salt it was 32.6 grams, and with a two-third ration it was 45.5 grams.

The individual results in series No. 5 were of such a character that no positive evidence of benefit was afforded when a one-third ration of sodium salt was added to a one-third ration of the potassium salt. However, the addition of a two-third ration of sodium salt was unaccompanied by apparent benefit. Supplementing the two-third ration of potassium salt with a two-third ration of sodium salt was evidently disadvantageous. The full ration of potassium salt supplemented with a sodium salt gave poorer result than the two-third ration of potassium salt when used alone.

If the benefit derived from the sodium in connection with the common spinach was actually attributable to its having liberated potash it would have naturally been expected that it would benefit millet distinctly, which was not the case. The other data seem to show that increased applications of potassium salts were usually beneficial even in the presence of the sodium salt, a fact which still further strengthens the idea that the sodium may have been of some physiological value to the common spinach when the supply of potassium was quite limited.

POT EXPERIMENTS WITH SODIUM SALTS IN 1899.

The pot experiments with sodium salts in 1899 were conducted with the identical soil and pots which were used in 1898, excepting that the soil of pot No. 35 was transferred to pot No. 80. Each pot in the entire lot received 2.3 grams of magnesium sulfate and 12.2 grams of dissolved bone-black. In addition, each received 2.3 grams of ammonium nitrate, which was applied in solution on July 4 just before watering the plants.

The full ration of sodium was supplied by 2.4994 grams of c. p. sodium sulfate, containing .15 per cent. of water, and the full ration of potassium was furnished in 3.0253 grams of dry c. p. potassium sulfate.

An attempt was made to grow common spinach in the pots in which the two kinds of spinach were grown the year before, but the seed was poor, and the stand was so irregular that crimson clover was finally substituted. This also so nearly failed as to render the results worthless.

Barley was planted twice in the pots which were devoted to barley the previous year, but the stand was so irregular that oats were finally planted in its place on June 22.

On July 4 the oat plants were thinned so as to leave sixty in each pot. The entire crop was harvested on August 25, before the seed was fully ripened, a procedure which was necessitated by the lack of suitable protection from birds. Below are given the weights of the material after it was oven dried in the laboratory:

Table Showing the Individual and Average Yields of the Oats.

Series No.	Pot No.	Rations of Potassium and Sodium Salts.	Grams of Dry Matter Produced.	Average Yield of Dry Matter in Grams. Entire Plant.
1	80 36 37	Potassium, full ration Sodium, $\frac{2}{3}$ ration	44.5 42.9 50.1	45.8
2	42 43 44	Potassium, $\frac{2}{3}$ ration Sodium, $\frac{2}{3}$ ration	47.9 47.0 47.7	47.5
3	49 50 51	Potassium, $\frac{1}{3}$ ration Sodium, $\frac{2}{3}$ ration	45.7 50.8 47.9	48.1
4	56 57 58	Potassium, $\frac{1}{3}$ ration Sodium, $\frac{1}{3}$ ration	47.2 45.9 49.4	47.5
5	63 64 65	Potassium, $\frac{1}{3}$ ration Sodium, none	45.0 53.4 51.6	50.0

Individual and Average Yield of the Oats.—Concluded.

Series No.	Pot No.	Rations of Potassium and Sodium Salts.	Grams of Dry Matter produced.	Average Yield of Dry Matter in Grams. Entire Plant.
6	70 71 72	Potassium, ⅔ ration Sodium, none	53.7 53.8 50.7	52.7
7	77 78 79	Potassium, none Sodium, none	43.1 43.4 43.1	43.2

In series 1, the results in two of the three cases were of such a character that no positive evidence of benefit from the employment of the two-third ration of sodium salt was afforded, even in the presence of the considerable amounts of potash which were unquestionably present in the soil naturally.

The use of a two-third ration of potassium salt seemed to have unquestionably increased the yield, as indicated by the average and individual results. The further addition of the sodium salt at the rate of a two-third ration apparently depressed the yield.

A one-third ration of potassium salt proved helpful in a slightly less degree than twice the amount, and when supplemented with a one-third and a two-third ration of sodium salt no apparent benefit resulted. It was most unfortunate that no data were secured with spinach, for they might have shown quite a different result from that secured with the oat, since the latter plant is probably the most powerful potash feeder among the cereals; and judging by other observations at this Station, it is probably far less likely to be helped by soda than many other varieties of plants.

Owing to the fact that the means for conducting further extended pot experiments were withdrawn, this particular line of experiments in ordinary soil was necessarily discontinued.

Experiments with Quartz Sand.

The quartz sand employed in this experiment was such as is used in the manufacture of sand-paper. It was nearly white but contained occasional colored particles. The sand was digested the greater part of several days with hot concentrated sulfuric acid and was then washed practically free from acid by the use of ordinary well-water coming from granitic rock, after which the balance of the necessary washing was done with distilled water. Six small pots were employed in the experiment, each of which contained between eleven and twelve pounds of sand.

The following materials were added to each pot, viz.:

1 gram calcium carbonate, c. p.

1 gram di-magnesium hydrogen phosphate, hydrous, c. p.

25 c.c. of a solution of c. p. calcium nitrate, containing 0.025 gram of nitrogen.

1 c.c. of c. p. ferric chlorid solution made by dissolving four grams of ferric chlorid in 100 c.c. of water.

The pots were next divided into three series, which received further materials as follows:

Series.	Pot Nos.	
No. 1.	1 and 2......	0.3700 gram c. p. potassium sulfate containing 0.200 gram of potassium oxid (K_2O) and 0.1700 gram SO_3.
No. 2.	3 and 4......	0.1850 gram c. p. potassium sulphate containing 0.085 gram of SO_3; and also 0.1513 gram of c. p. sodium sulfate containing 0.085 gram SO_3.
No. 3.	5 and 6......	0.1850 gram c. p. potassium sulfate containing 0.085 gram SO_3; and also 0.1812 gram of c. p. calcium sulfate containing 0.085 gram SO_3.

On August 8, 1900, twenty-seven barley seedlings were set in each pot. The pots were kept in the laboratory and glasshouse until April 6, 1901. The plants throughout failed to thrive properly. Following the barley, spring rye was planted, but after some time

its unhealthy appearance became so marked that the reaction of the sand upon litmus paper was tested, whereupon it was found to be alkaline. Accordingly all of the pots were watered with equal amounts of very dilute nitric acid, which resulted in marked improvement, though the plants never possessed a perfectly normal appearance. It is possible that at least a part of the benefit derived from the nitric acid may have been due to its supplying nitrogen to the plants as well as acting as a neutralizer of alkalinity.

Below are given the weights of thoroughly air-dried material obtained in the two crops:

Series.	Pot No.	Barley Plants, Grams.	Rye Plants, Grams.
No. 1.	1	4.32	2.89
	2	6.05	1.67
No. 2.	3	3.79	2.00
	4	4.41	2.11
No. 3.	5	6.85	2.10
	6	5.82	1.20

Taking both crops into consideration, the results in series 3, where calcium was substituted for some of the potassium, were better than in series 2, where sodium was substituted. The conditions of the experiment and the individual results are so variable, however, that it seems probable that other factors had more to do with the size of the crop than the presence or absence of sodium, and little weight is attached to the results in their bearing upon the question of the utilization of sodium in the absence of sufficient potassium.

During the growth of the first crop the lower leaves were continually dying, and there was an unusual roughness to the leaves suggesting the accumulation of excessive amounts of silica. The data are given here merely to show what occurred under the conditions, and not on account of their being of particular value in their bearing upon the soda question.

It is hoped that the results may possibly prove of aid to others who may be investigating this subject.

EXPERIMENTS IN SAND CULTURE IN 1905.

The same kind of sand was employed in this experiment as in that described above, though it was not previously digested with acid. The zinc pots which were employed were of the Wagner pattern, eight inches deep and eight inches in diameter. They were coated on the inside with paraffin in order to obviate in so far as possible any danger from zinc poisoning. Seven kilograms of the sand were placed in each pot. The dry sand absorbed water to the extent of 2.8 kilograms per pot. All of the pots received the following materials:

2.00 grams di-magnesium hydrogen phosphate, hydrous, c. p.

0.320 gram potassium chlorid, recrystallized.

0.215 gram calcium carbonate, c. p. (equivalent to the amount of chlorin in the potassium chlorid).

0.200 gram calcium sulfate, c. p.

2 c.c. ferric chlorid solution (4-100).

25 c.c. calcium nitrate solution (containing 0.025 gram of nitrogen).

Pots Nos. 104 and 105 received nothing further.

In addition to the applications in the pots just mentioned, pots Nos. 106 and 107 received each 1.16 grams of c. p. sodium chlorid. Pots Nos. 108 and 109 received 1.66 grams of c. p. calcium chlorid in place of the sodium chlorid.

One-half of the above amounts of sodium chlorid and of calcium chlorid per liter should, according to Pfeffer, produce the same osmotic pressure.

On May 18 twenty-five selected sprouted seeds of the early long scarlet radish were planted in each pot, after which two liters of water were also added to each. The pots were placed on trucks and were kept out of doors or under the shelter of a glasshouse, as necessitated by the climatic conditions. The desired number of good plants was for various reasons, not obtained, one of which was that the sand

seemed to hold the leaves down so that the roots tended in some cases to turn upward. Accordingly on June 1st nineteen unsprouted seeds of the largest size were planted in each pot at a depth of one inch and covered lightly. On June 9 a second application of 25 c.c. of the calcium nitrate solution was made to each pot. The same application was made again on June 17. Red litmus paper was found at this time to be turned blue in spots when pressed between the sand grains, which was supposedly due to the presence of small particles of the calcium carbonate which was originally introduced into the sand. The plants were abnormally light green in color, and the petioles, veins, and edges of the leaves had a reddish hue.

On June 19 a solution containing 2 c.c. of nitric acid (Sp. gr. 1.42) in 2,000 c.c. of water was prepared and 100 c.c. of this solution were added to each pot. The plants did not make a normal growth at any time, notwithstanding that a solution of calcium nitrate was added from time to time to insure that there should be no lack of nitrogen. The lower leaves continued to die and drop off, thereby adding a certain amount of organic matter to the sand.

Thirteen plants were finally left in each pot. On September 11 some of the plants in pot No. 104 gave such marked evidence of dying that the plants in all of the pots were harvested. The roots were long and fibrous and were tenaciously attached to the sand, and many of the plants failed to develop in the usual form.

Below are given the diameters, at the largest place, of the radishes in each pot, which exceeded 6 m.m. in diameter:

Pot No.	No. of Plants.	No. of M.M. in Diameter.
104	5	15–16–10–9–7.
105	7	8–13–8–13–17–10–7.
106	9	8–13–11–11–18–9–8–12–10.
107	7	7–12–10–12–11–14.
108	8	10–17–9–11–12–11–11–10.
109	9	12–13–14–15–12–9–9–13–9.

The material harvested represents the entire plants. Below are given the relative weights of oven-dry material:

Pot No.	Potassium Chlorid and Other Chlorids Applied.	Weight in Grams.
104	Small amount of potassium chlorid	2.394
105	but neither sodium nor calcium chlorid	2.246
106	Same potassium chlorid as Nos. 104 and 105	3.584
107	plus sodium chlorid, but with no calcium chlorid	2.920
108	Same potassium chlorid as above, plus calcium chlorid	4.521
109	but no sodium chlorid	3.791

Such indications as are afforded by this experiment are to the effect that better results were secured by adding either sodium chlorid or calcium chlorid to the potassium ration than by the use of the latter alone, and that the sodium salt was probably less efficacious than the calcium chlorid. The data are, however, too few and the individual results too variable to justify drawing any conclusions on this particular point, and they are merely presented as a matter of record with the hope that they may have some future value by way of comparison with other possible experiments here, or elsewhere. Below are the analytical data that were obtained in connection with the total product of each of the three series of pots:

Early Long Scarlet Radish, Entire Plant. Grown in Quartz Sand, 1905.

Pot No.	Grams, Dry Matter.	Per cent. in Dry Matter.				
		Crude Ash.	Silica (SiO_2).	Soda (Na_2O).	Potash (K_2O).	Phosphoric Acid. (P_2O_5.)
104	2.394	28.321	11.069	1.206	3.562	1.894
105	2.246	25.481	6.385	1.357	3.724	1.710
106*	3.584	20.887	4.233	3.667	2.392	1.911
107*	2.920	22.062	5.322	3.592	1.920	1.412
108†	4.521	18.133	3.338	0.763	3.242	1.479
109†	3.791	18.056	3.197	0.672	3.572	1.744

*With addition of sodium chlorid.
†With addition of calcium chlorid

The preceding results give indications, as has been said, that sodium chlorid was less helpful than calcium chlorid, or quite the opposite result from that obtained in somewhat similar experiments by Atterberg.* It is evident, from the medium used and from the analyses, that the influence of these salts must have been other than as liberators of potassium or as substitutes for that element. In fact it will be observed that the percentages of potassium oxid in the plants were depressed by the addition of sodium, from 3.562 and 3.724 to 2.392 and 1.920, at the same time the percentages of sodium oxid in the crop were almost trebled notwithstanding that those of phosphoric acid were not materially affected. At the same time the percentages of silica, which were 11.069 and 6.385 without the addition of soda, dropped to 4.233 and 5.322; and where the calcium chlorid was used they dropped to 3.338 and 3.197. It cannot well be claimed that the benefit from the sodium chlorid was due to direct manurial action, for the growth with calcium chlorid was still better, with only about half as much soda in the dry matter, than where neither the sodium nor calcium salt was employed. The inference seems to be that the poor growth was due very largely to the fact that the silica was highly soluble and that the entrance of large amounts of it into the plant inhibited growth. It is of interest that the calcium chlorid should have proved beneficial when one recalls that some calcium carbonate had been used in all of the pots.

It appears probable that a part of the benefit from using the sodium and calcium chlorids may have been due to the union of the bases with the soluble silica, by which zeolitic compounds were formed, in consequence of which the entry of such large amounts of silica into the plant became impossible, or else these salts lessened the ionization of silicon compounds.

The sand which has just been mentioned had not been treated with hydrochloric, nor other, acid. In this connection it will be recalled that Hellriegel and Wilfarth† state that sand which has been treated

*Deut. Landw. Presse, 1891, p. 1035, Abs. E. S. R., 3, p. 554.
†Arb. Deut. Landw. Gesell. (1898), Heft. 34, pp. 20, 21.

with hydrochoric acid must be heated to at least 400° C. in order to make it a suitable culture medium for plants; and they confess to a doubt whether the benefit from heating was due to removal of final traces of hydrochloric acid or to rendering the silica more insoluble, though they incline to the latter view. These results therefore confirm the idea that the rendering of the silica insoluble was probably the chief reason for benefit by heating, and they further indicate that crushed silica, whether treated with acid or not at the outset, should probably be heated to 400° C. before using in culture experiments. It is hoped, therefore, that though this experiment failed in its prime object it may have thrown useful light upon the conditions essential to success in sand culture.

CONCERNING THE PRESENCE OF SODIUM IN PLANTS.

The presence of more or less sodium in cultivated plants seems to be practically universal, yet the quantities present in different portions of any given plant may vary widely.

Peligot, who, according to Pagnoul,* first pointed out the difference in the action of sodium and potassium upon plants, made soda determinations in many varieties of plants† and claimed that the ash of most agricultural plants, including spinach, contained none, yet he found it in species of *Atriplex* and *Chenopodium* and in fodder beets.

Bunge‡ called attention to the fact later that the method of analysis employed by Peligot was not reliable. Peligot, however, repeated some of his earlier work,§ taking special precautions against the loss of soda, as a result of which he again declared that the ash of certain plants contains no soda whatever. Dehérain|| also asserts that potatoes grown in some of his own experiments, in which sodium salts were used as manures, were found to contain no sodium.

*Ann. Agron. 20 (1894), p. 467.

†Compt. Rend. Acad. Sci. [Paris], 2 (1867), p. 729; and later issues of the same journal.

‡Annal de Chem. und Pharm. 172, p. 16.

§Compt. Rend. Acad, Sci. [Paris], 76 (1873), p. 1113. Abs. Centbl. Agr. Chem. 4 (1873), pp. 222–226.

||Ann. Agron. 9 (1883), p. 511.

As early as 1875 Pagnoul* stated that potatoes manured liberally with potassium contained no sodium whatsoever, not even though sodium was present in the soil. Later Pagnoul† states that sodium may be absent entirely if large amounts of potassium salts are used as manures. He further adds that when sodium salts were applied in large quantities to a white silicious soil, potatoes contained notable quantities of it, but he claimed that in an ordinary cultivated soil, under the same conditions, appreciable quantities of sodium would not be present in the tubers. Oats he found to absorb soda in case potash was lacking.

Sjollema‡ says that soda is not present in potato tubers, even when large amounts are applied in the manures. C. A. Cameron§ also found it almost wanting in potatoes grown within a few feet of the ocean, and other tubers grown further inland, where there was less soda, actually contained more of it.

Zöller|| found 5.10 per cent. of soda in the ash of the stems of beans which had received sodium salts in the manures, but where the sodium salt was not employed the percentage in the stems amounted to but 1.36.

It has been stated that Contejean and Guitteau** determined the percentages of potash and soda in over 600 varieties of plants. Abundant data are to be found in Wolff's familiar tabulation of ash analyses, and it only remains to add that the percentages of soda vary greatly from the minute quantities which may be present in the potato tuber to about 40 per cent., the amount reported by Hilgard†† to have been found in the ash of the grease-wood (*Sarcobatus vermiculatus*).

E. von Wolff‡‡ gives a fine illustration of the wide variations in the

*Compt. Rend. Acad. Sci. [Paris], 80 (1875), p. 1010. Abs. Jahresber. Agr. Chem. 18, p. 259.
†Ann. Agron. 20 (1894), pp. 467–479.
‡Jour. Landw. (1899), p. 357.
§Abs. Jahresber. Agr. Chem. 4, p. 148.
||Jour. Landw. (1867), p. 309.
**Compt. Rend. Acad. Sci. [Paris] (1878), 86 pp. 1151–1153; Abs. Centbl. Agr. Chem. (1879), p. 38.
†† Jahresber. Agr. Chem. (1892), p. 183.
‡‡Landw. Vers. Stat. 10, p. 371.

relative amounts of soda and of potash which resulted in oat plants grown in water-culture experiments. It is useless here to further multiply illustrations of this character. One cannot wonder, under the circumstances, that the attention of both agricultural chemists and plant physiologists was long since directed to the solution of the problem of the action which sodium exerts upon the soil and to its functions in the plant.

Sodium as an Indirect Manure.

It has already been abundantly established by various experimenters that upon applying sodium salts to ordinary soils, soluble compounds of potassium are usually formed, and the very high efficiency of sodium chlorid in this particular, under exaggerated conditions, has been well shown by Passerini.*

B. Dyer† claimed that common salt had a high value "as a dressing for cabbage when a sufficiency of other manurial ingredients is present." It seems doubtful, however, if he was sure of the "sufficiency" mentioned. At all events, upon soils where the German golden millet and certain other plants thrive almost to perfection, the cabbage may fail completely from lack of phosphoric acid, in view of which the sodium salt may have proven beneficial by virtue of liberating phosphoric acid. Storer‡ cites Dyer to the effect that common salt seems to be needed to bring out the full action of phosphates and nitrates.

Birner and Lucanus§ in their early work found that sodium sulfate favored the passage of phosphoric acid into the plant, but that it lowered the percentage of lime taken up. They also found, upon applying potassium chlorid, that the ash and dry matter of the plants were richer in magnesia and potash but poorer in lime, sulfuric acid, and phosphoric acid. However, they found that the application of

*Quorta Seine, Vol. 17, Dist. 1a–2a (Vol. 72 delea Ralcolta Generale, 1894), p. 15. Kindly translated for us by Prof. Penny of Delaware.

†Jour. Royal Agr. Soc. Eng. (1887), p. 429.

‡Agriculture II (1897), p. 595.

§Landw. Vers. Stat. 8 (1866), p. 140.

sodium chlorid caused lime, sulfuric acid, and phosphoric acid to be taken up even more slowly than before, but at the same time the percentage of both potash and magnesia in the plant was increased. Müntz and Girard, as previously quoted, say, concerning a solvent action of sodium chlorid upon soil phosphates and upon potash in silicate combinations, that if this action exists it must be extremely limited. Nevertheless it must be recognized that Müntz and Girard make a somewhat broad assumption when one considers that the soil phosphorus may exist in several different combinations. Similarly, in the case of potassium, the liberating action of sodium chlorid would be vastly different, dependent upon the relative abundance of zeolites, glauconite, feldspar, and possibly other potassium-bearing silicates. At all events our own experiments, covering several years, made with a large variety of plants, have shown an unmistakable general tendency of both common salt and sodium carbonate to increase phosphorus percentages in the crops.* The action in this particular upon lime and magnesia was but slightly marked, or uncertain, in comparison.

CONCERNING THE BENEFIT TO CROPS FROM APPLYING SODIUM SALTS.

The fact that benefit, either direct or indirect, is often derived from applying common salt to the soil is too generally known and accepted to seem to need further substantiation. It also acts more beneficially with some varieties of plants than with others. According to Griffiths† about 250,000 tons of finely crushed salt are used annually for manurial purposes in the United Kingdom of Great Britain.

It seems to be an established fact that sodium salts may exert an influence upon plant growth by changing the chemical reaction of the soil or other medium in which the plant is grown; for example, Prianischnikov‡ found that when using sodium nitrate as a source of nitrogen for plants, the medium became alkaline by virtue of the removal of more nitric acid than of soda by the plants. That such

*See pages 194 to 219.

†A Treatise on Manures (1889), p. 256.

‡Chem. Ztg. 66 (1900), p. 701.

a change, causing either greater acidity or alkalinity, will materially influence plant growth has been sufficiently shown by the earlier experimenters who grew plants by way of water culture. The recent experiments made in the field with ammonium salts by Voelcker at Woburn, England, and also with ammonium sulfate at the Rhode Island Station, have well illustrated the acidic tendency of such manures.

The well-known toxic action of the black alkali in the soils of the arid regions, by which they are made too alkaline, is too familiar to require further mention.

INFLUENCE UPON THE CONSERVATION AND MOVEMENT OF WATER.

H. Ricôme* claims to have shown in experiments with *Malcolmia maritima* and *Alyssum maritimum* that the presence of sodium chlorid in the solution outside of the plant lessened the water absorption and also tended to protect the plants from too intensive water transpiration. The presence of the sodium salt within the plant itself did not appear to hinder the transpiration unless the conditions were also such as to render the absorption easier.

It is recognized, as is stated by King,† that the presence of soluble salts increases the surface tension of liquids, and hence they aid in increasing the rate of capillary movement of the soil water towards the surface or toward the roots of plants.

It is generally contended by practical farmers that the presence of common salt in soils aids in the retention of moisture and that it may therefore act beneficially, especially upon light soils which are likely to suffer from drought. This practical observation has been supported by careful scientific observations, for King‡ states that the presence of salts lessens evaporation from the surface so long as they remain in solution, and in case some of them separate out at the surface they then act in a measure the same as a mulch.

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*Compt. Rend. Acad. Sci. [Paris] 137 (1903), p. 141. Abs. in Centbl. Agr. Chem. 33 (1904), p. 224.

†A Text Book of the Physics of Agriculture (1901), p. 106.

‡l. c.

PLANT GROWTH AS INFLUENCED BY THE EFFECT OF SODIUM UPON OSMOTIC PRESSURE.

It seems to have been satisfactorily established that there may be circumstances under which the addition of common salt or of other soluble salts to solutions aids the growth of plants solely by virtue of increasing the osmotic pressure. In how far one may speculate upon such benefit when the addition is made directly to the soil, is a question that may well be considered open for discussion. It may readily be seen that owing to the fixing or absorbing power of soils it is not safe to expect that salts applied to the soil will have the same effect as when applied in solution, or that the effect will be lasting in its character. Water-culture investigations are now in progress to attempt to ascertain if the sodium salts were probably beneficial on this account.

CONCERNING POSSIBLE PHYSIOLOGICAL FUNCTIONS OF SODIUM.

It appears to be so universally conceded that sodium can not fully replace potassium in its physiological functions in connection with the growth of agricultural plants that it seems wholly unnecessary to make an array of the high authorities in practically every civilized land to that effect. It is of interest to observe that most of those who have written upon this subject seem to assume that potassium has but one physiological function, namely, that of aiding in the formation and translocation of starch. Benecke* suggests that sodium may aid in maintaining the turgor of plants by the performance of osmotic service in the place of potassium. Concerning potassium in its relation to turgor, Copeland† says that it is a factor, direct or indirect, in maintaining the turgor of the plant, and that when phosphorus, magnesium, and sulfur were omitted there was poor growth but high turgor; but that in the absence of potassium the growth was stunted and the turgor decreased. In this connection

*Ein Beitrag. zur. mineralischen Nahrung der Pflanzen, Ber. Deut. Bot. Gesell. 12 (1894), General Versammlung, p. 114. Quoted from Copeland.

†Bot. Gaz. 24 (1897), p. 411.

it may be mentioned that De Vries* held for some time that organic acids were of primary importance in maintaining turgor, a position from which he receded later.† It seems to be held that growth may occur without turgor and that unusually rapid growth may lessen it. According to Pfeffer, turgor can not supply the energy necessary for growth, hence it is rather a result of the conditions of, than itself a cause of, growth; hence Pfeffer considers turgidity as only of accessory importance.

Concerning the association of potassium, only with the function of aiding in the formation and translocation of carbohydrates, Pfeffer‡ holds that phosphorus may be as essential as potassium, and he adds that "the function of an essential element is by no means directly indicated by the result which its absence produces." In this connection attention should be called to the fact that sodium has been found, in the course of our own experiments, to have been a carrier of phosphorus to the plant.

In some cases, according to Goodale,§ sodium may be substituted for a part of the potassium which would otherwise be needed by the plant.

Mention is made by A. Mayer of the free movement of sodium salts in the plant, and he suggests that the sodium may combine with organic acids, without having special physiological significance, on the ground that it makes no difference to the plant what particular metal is thus combined. At this point it is of interest to call attention to the experiments by Mercadante,|| who grew species of *Oxalis* and *Rumex* without potassium. As a result neither flowers nor fruit were formed, and only one-eighth of the normal amount of acid was present. The oxalic and tartaric acids which were produced were found in combination with lime, and only small amounts of sugar and starch were found in the sap of the plant. It is known that under normal conditions of growth the organic acids which are said to be

*Bot. Ztg. 1879, p. 848.
†Pfeffer: The Physiology of Plants. Translated by Ewart (1900), Vol. I, p. 141.
‡Ibid, Vol. 1, p. 424.
§Physiological Botany (1885), p. 255.
||Abs. Jahresber. Agr. Chemie, 8, p. 257.

formed in the process of the synthesis of the proteids* are often found combined in part with potassium. It is also asserted by Schimper† that the neutral, and more especially the acid, salts of potassium and oxalic acid which may result if lime is lacking, are themselves poisonous; nevertheless it may be necessary that oxalic acid combine at first with a base like sodium or potassium while being transported to other parts of the plant where it can be precipitated out as oxalate of lime, whereby it ceases to interfere with the physiological functions. In other words, the presence of oxalates of the alkalis in small amounts may be essential to the welfare of the plant, even though in large quantities they may be inimical to its growth. Whether in the absence of sufficient potassium, sodium may be of use merely to combine with and aid in the disposal of organic acids in the plant, is a point which it might if possible be of interest to determine.

From water-culture experiments with maize, Stohmann‡ concluded that sodium was an element essential to its perfect development. It is held by Müntz and Girard§ that if soda is ever essential to plants it may be in connection with the mangel-wurzel. Sodium, according to Aikman,|| is possibly essential to plants in minute quantities; and A. Mayer,** though he believes that for certain plants soda may not be essential, warns against making a general deduction to this effect, since he thinks that the large amount of sodium in certain plants may be a hint that they require it or are in some way benefited by it.

It is held by Salm-Horstmar†† that for wheat and oats, sodium is advantageous, but that it is necessary only for the perfection of the seed. According to Johnson,‡‡ if sodium is indispensable, only minute quantities are necessary to plants.

*Schimper; Zur Frage der Assimilation der Mineralsalze durch die gruene Pflanze.

†Flora (1890), pp. 207–261.

‡Jour. Landw. (1862), p. 25.

§Les Engrais, Vol. 3, p. 153.

||Manures and the Principles of Manuring (1894), p. 55.

**Lehrbuch der Agrikulturchemie I (1895), p. 283.

††Versuche und Resultate ueber die Nahrung d. Pflanzen Braunschweig (1856), pp. 12, 27, 29, and 36.

‡‡How Plants Grow (1891), p. 189.

More recently Atterberg* conducted experiments in quartz sand in which he substituted in one case calcium and in the other sodium for a part of the potassium, with the result that the yields fell off in a far greater degree when calcium was substituted than when he used the sodium. From this work he drew the conclusion that sodium was by no means a useless ingredient in manures, but that when the supply of potassium is limited it may perform a very useful function in connection with plant growth. The following year Wagner and Dorsch† also made strong claims for the direct manurial action of sodium, asserting that when the supply of potassium was limited to a small amount, the employment of sodium in its capacity as a *direct* manure increased the crop one-half.

Following shortly after the publication of these results by Atterberg, and Wagner and Dorsch, Stahl-Schroeder‡ published certain researches which seemed to contradict their work. In this connection the claim was made that the media in which the plants were grown by Atterberg, and Wagner and Dorsch, doubtless contained potassium which was liberated upon the application of sodium salts; and that the sodium had not acted as a direct manure. Thus he essayed to show that the conclusion of these experimenters was utterly faulty. The matter was of so much interest, in view of the fact that Atterberg was reported to have used "pure silica" in which to conduct his experiments, that one of us (H. J. W.) wrote to him asking if the silica in which the plants were grown was actually analyzed, and if so, what percentages of both sodium and potassium were really present. In response to this inquiry it was stated that a surprising amount of sodium was found in the crop in certain cases where it was not to be expected, and he stated that it evidently came from the sand, which was found to contain sodium chlorid. Furthermore, the asphalt paint which was applied to the interior of the pots contained considerable quantities of some mineral matter. It was not stated, however, whether or not the silica and paint were tested for

*Deut. Landw. Presse (1891), p. 1035.
†Die Stickstoffdüngung d. landw. Kulturpflanzen (1892), pp. 227–242.
‡Jour. Landw. 47 (1899), pp. 49–84.

potassium, hence it is reasonable to infer, in view of the presence of such considerable amounts of sodium, that potassium may have been present and may have been set free by the sodium salts which were employed. It is greatly to be hoped, therefore, that Prof. Atterberg will repeat his experiments with a medium demonstrated at the outset to be free from potassium.

Still more recently Pfeiffer* and his co-workers have been studying the action of sodium salts in connection with barley, and as a result of their investigations and critical study of the experiments by Hellriegel and Wilfarth, and also by Doll and others, they have arrived at the conclusion that, aside from the action of sodium salts in liberating potash in the soil, they also replace some of the potash in the leaves and stalks, in consequence of which more potash is at the disposal of the plant to use in the formation of the seed. Such benefit would of course only be expected in cases where there exists an actual shortage of potassium. In their own experiments little evidence was afforded of an actual replacement of potassium by sodium in the seed itself to the advantage of the plant, yet they cite experiments by Doll, Hellriegal, and Wilfarth which seem to them to justify the view that benefit, even in that direction, may result.

During the summer of 1905 Breazeale,† while engaged in co-operative experiments between the Bureau of Soils of the U. S. Department of Agriculture and this Station, undertook experiments which suggested themselves to him after a study of our own pot and field work, and found that plants which had been grown for a time in a solution containing sodium, took up far less potassium when transferred to a full nutrient solution, than those which had been kept under the same conditions and for the same length of time in a solution from which sodium was excluded. From this the inference might be drawn, particularly in view of the better growth and transpiration during the preliminary and final stages in those cases where the sodium salt was used at the outset, that the sodium had lessened

*Mitt. Landw. Inst., Breslau (1905), pp. 567–613.
†Jour. Amer. Chem. Soc. 28, p. 1013.

the requirements for potassium and that therefore some physiological function was probably to be attributed to the sodium salt.

Pember, of the Bureau of Soils of the U. S. Department of Agriculture, and Hartwell are at the present time engaged in similar co-operative work making water-culture tests as suggested by two of us (H. J. W. and B. L. H.). The results thus far obtained are given below.

In experiment I, where both a one-fourth and a one-eighth "ration" of the potassium salt was supplemented by the calcium salt, the transpiration and green weights were both lessened, and by the addition of the sodium salt both were decidedly increased.

In experiment II the results were somewhat unsatisfactory owing to the prevailing climatic conditions; the results, however, when only a one-eighth ration of potassium was used, agree with those in experiment I, excepting for the low transpiration when the extra seven-eighth ration of the sodium salt was used. In other words, in this case the green weight was materially increased by using the sodium salt, notwithstanding that the transpiration figures failed to point in the same direction. The addition of the calcium salt to the one-eighth ration of potassium salt appeared both by transpiration and green weight to have been beneficial, but in a far less degree than the added sodium.

In experiment III the addition of the calcium apparently increased the transpiration and green weights more or less in both cases, but in a far less degree, with one exception, than the sodium.

In experiment IV with a one-eighth ration of potassium the calcium seemed to be beneficial as far as concerned the green weight, but in both cases the results with sodium were far superior to those with extra calcium. When a one-fourth ration of potassium was used the transpiration and yields were smaller in both cases upon the employment of the extra calcium salt, but both were increased by the addition of the sodium salt.

In experiment Va and Vb, excepting the smaller green weight in series Va, the use of the additional calcium salt was followed by

gains in both transpiration and green weight, while a most marked gain in both resulted when the sodium salt was added.

The amounts of total solids were the same in all cases in a given experiment, excepting where only a one-eighth or a one-fourth ration of potassium was applied. If it were argued that the difference in the osmotic pressure produced by the calcium and the sodium accounted for the greater gain from the latter, it would be expected that the calcium would have proved helpful in all cases and far more so than in most of the instances. Furthermore, increased amounts of the calcium and sodium salts have been added to the potash ration in other series of experiments now in progress, but without certain increased benefit, a fact which leads one to infer that the great benefit observed from the sodium in this instance can not have been wholly or even largely due to influencing the osmotic pressure. It will be observed that these culture experiments were conducted in solutions, thus eliminating indirect manurial action; hence there seems no escape from the conclusion that the benefit must have been physiological in character, particularly when it is stated that less potash was frequently removed from the solution when sodium was added than when it was not. It is proposed, nevertheless, to pay particular attention, if feasible, in future experiments to the possibility of differences in the chemical reaction of the solutions when the soda is employed and when it is not used, yet it appears hardly probable that this will serve to explain the differences in results. It is desirable that it be ascertained, if possible, whether the good effect of the sodium salts in water culture can have been due to changing in a beneficial way the relationships of lime and magnesia and possibly other mineral plant ingredients.

It is mentioned by Schneidewind* that Hellriegel and Wilfarth produced, with more soda and less potash, the same amount of dry matter and sugar as where a larger quantity of potash was employed; nevertheless he believes that the advantage of soda which he has frequently observed in his experiments with beets was due primarily

*Jour. Landw. (1898), p. 7, 8.

not to physiological functions but rather to the greater solubility of the sodium than of the potassium salts of nitric, phosphoric, and sulphuric acids, on account of which they more readily entered the plants.

S. Suzuki* calls attention to an interesting possibility concerning sodium in plants, for he recalls the work of Chittenden showing that the efficiency of vegetable diastase is increased by small amounts (0.24 per cent.) of sodium chlorid, just as has been shown by Wachsmann† to be the case with animal diastase. He also cites that A. Mayer‡ found that a 1 per cent. solution of potassium chlorid retarded diastatic action, while smaller quantities exerted no decisive result. Hence Suzuki suggests a physiological function of sodium chlorid in plant growth by virtue of its possibly acting with diastase in the transport of starch to the growing tips of plants, thus explaining the function in connection with starch in an indirect rather than in a direct way.

It seems by all means desirable that far more definite knowledge should be gained concerning the functions of sodium than that which we now possess, and furthermore it should be definitely ascertained what varieties of plants are most likely to be benefited by sodium salts when there is a lack of potassium salts. Such information will place the farmer in far better position to know when to employ advantageously manures rich in sodium salts, such as nitrate of soda and kainit, as a sort of insurance against a depression of yield on account of a deficiency of potash. Furthermore, the conditions under which sodium salts may conserve the potash stores within the soil should be thoroughly studied, and it should be ascertained with what agricultural plants such a conservation of potash is possible, or, in other words, what plants may be prevented from overfeeding on potash if provided with soda.

*Bul. Col. Agr. Tokio, Imp. Univ. 6 (1905), No. 4. p. 408.
†Pflueger's Archiv. 91 (1902), p. 191.
‡Jour. f. Landw. 49, p. 57.

SUMMARY.

These experiments show that in the presence of very limited supplies of potassium salts, sodium salts may greatly increase the yields of certain crops.

In the case of the mangel-wurzel, similar benefit from sodium salts occurred when as much as 332 pounds of muriate of potash, or its equivalent of potassium carbonate, were employed per acre. Also, in connection with certain other plants, similar, though less marked, benefit from sodium salts was observed even when the applications of potassium salt were large.

Sodium salts were found to increase the percentage of phosphorus in the plant. In this respect the carbonate was more efficient than the chlorid. The results furnish much evidence to show that this was an incidental accompaniment of the employment of the sodium salts rather than the cause of the increased growth which resulted. This feature should nevertheless be further investigated.

Little evidence was secured to indicate that the benefit to plant growth caused by the sodium salts was due to changing the ratio of lime and magnesia in the plants.

The sodium salts undoubtedly acted as indirect manures by virtue of liberating potash, yet strong evidence was afforded that the potassium taken up by the plant was often more economically utilized, or in other words a greater crop was produced, when sodium salts were applied in the manures and when relatively more sodium entered the plant.

The water-culture investigations show unquestionable benefit, under certain conditions, from the employment of sodium salts in the presence of limited supplies of potassium, which is not attributable to liberation of plant food, effect upon soil moisture, etc. This benefit does not seem to be wholly or chiefly explainable upon the ground that the sodium salts had increased the osmotic pressure, for calcium salts failed to have the same marked effect.

In the dry season of 1899 strong evidence was afforded that appli-

cations of sodium salts to the soil prevented the plants from taking up and removing unnecessary amounts of potash, or in other words the sodium seemed to conserve the potassium of the soil. In the wet season of 1901 the contrary apparently resulted. This indicates the necessity of a more careful study of the conditions affecting the beneficial action of sodium salts and the danger of drawing definite and final conclusions from a single experiment.

The results do not indicate that it would be wise to purposely cut down the supplies of potassium enough to make sodium salts beneficial, for fear of depressing the crops, nor to buy common salt nor sodium carbonate for the purpose of attempting to conserve the potassium in the soil; yet the sodium in the potash salts and in nitrate of soda, which practically costs nothing, may often increase certain crops if a shortage of potassium occurs.

The results go to show that the beneficial influence of sodium salts is largely conditioned upon the variety of plant, and this is a field of investigation that has as yet remained grossly neglected, not only in this country but also in Europe.

It is proposed to further study the influence of sodium salts upon the reaction of the medium and the bearing of this influence upon the growth of plants, also the possible influence of the sodium in changing the ratio of other mineral ingredients taken from solutions by growing plants. In short, it is hoped by these and other means to throw additional light upon the physiological functions of sodium and the practical significance of sodium salts in agriculture.

A study has been begun of the influence of the application of varying proportions of sodium and potassium salts upon the organic constituents of certain plants.

APPENDIX.

A COMPLETE COMPILATION OF THE ANALYTICAL PERCENTAGE DATA IN THE FOREGOING DISCUSSION.

GOLDEN MILLET, 1898.

	Unlimed Carbonates.		Limed Carbonates.	
Soda ration	1	¼	1	¼
Potash ration	¼	¼	¼	¼
Plat No.	27	36	39	48
Crude ash	9.18	7.75	8.97	8.62
Silica and insol. matter	4.76	3.80	3.77	3.03
Phosphoric acid	.79	.63	.71	....
Sulfuric acid	.53	.53	.35	.48
Potassium oxid	.97	1.09	1.09	1.16
Sodium oxid	.17	.14	.07	.05
Calcium oxid	....	....	.88	....
Ferric and aluminic oxids	.21	.18	.14	....
Yield, green, pounds	102	132	155	142

WHITE STRASBURG RADISH (ROOTS), 1899.

	Unlimed Chlorids.			
Soda ration	1	½	1	¼
Potash ration	½	½	¼	¼
Plat No.	2	6	8	12
Nitrogen	3.31	3.19	3.68	3.42
Crude ash	23.22	20.87	22.49	17.51
Silica and insol. matter	....	.11	.12	.15
Phosphoric acid	1.02	.98	1.13	1.02
Potassium oxid	6.72	6.12	3.76	3.69
Sodium oxid	4.14	3.67	6.38	3.83
Calcium oxid	1.06	1.02	1.09	1.38
Magnesium oxid	.58	.65	.67	.73
Yield, green, pounds	834	797	709	547

WHITE STRASBURG RADISH (ROOTS), 1899.

	Limed Chlorids.				
Soda ration	1	½	1	¼	0
Potash ration	½	½	¼	¼	1
Plat No	**14**	**18**	**15**	**24**	**22**
Nitrogen	3.71	3.74	3.54	3.53	....
Pure ash and insol. matter	....	....	16.11	14.47	17.74
Crude ash	24.14	20.35	....	....	....
Silica and insol. matter	.17	.12	.16	.29	.17
Carbon dioxid	....	....	3.29	3.32	3.78
Phosphoric acid	.90	.84	.98	.89	.78
Sulfuric acid	....	....	1.96	1.84	....
Potassium oxid	5.19	5.54	2.85	3.62	8.43
Sodium oxid	5.12	3.62	6.01	4.03	2.02
Calcium oxid	1.32	1.43	1.19	1.56	1.46
Magnesium oxid	.63	.56	.73	1.02	.89
Yield, green, pounds	766	662	685	432	709

WHITE STRASBURG RADISH (ROOTS), 1899.

	Unlimed Carbonates.			
Soda ration	1	½	1	¼
Potash ration	½	½	¼	¼
Plat No	**26**	**30**	**29**	**36**
Nitrogen	3.80	3.47	3.74	3.33
Crude ash	22.63	20.47	21.49	17.33
Silica and insol. matter	.07	.05	.08	.11
Phosphoric acid	1.13	1.05	1.13	.99
Potassium oxid	4.98	5.59	2.90	3.05
Sodium oxid	4.50	3.60	6.57	3.56
Calcium oxid	1.23	1.24	1.27	1.17
Magnesium oxid	.90	.75	.94	.77
Yield, green, pounds	817	776	722	547

WHITE STRASBURG RADISH (ROOTS), 1899.

	Limed Carbonates.				
Soda ration	1	½	1	¼	0
Potash ration	½	½	¼	¼	1
Plat No	**38**	**42**	**39**	**48**	**46**
Nitrogen	3.85	3.59	3.60	3.77	....
Pure ash and insol. matter	....	....	15.33	13.88	18.10
Crude ash	28.40	22.54	....	....	....
Carbon dioxid	....	....	4.54	3.38	5.05
Phosphoric acid	1.10	1.05	1.08	.96	.96
Sulfuric acid	....	....	2.35	1.97	....
Potassium oxid	5.27	5.48	2.81	3.61	9.82
Sodium oxid	5.72	4.07	6.50	3.69	1.43
Calcium oxid	1.17	1.19	1.07	1.53	1.61
Magnesium oxid	.67	.72	.76	1.17	1.10
Yield, green, pounds	662	621	540	432	655

FLAT TURNIP (ROOTS), 1899.

	Limed Chlorids.			Unlimed Carbonates.	
Soda ration	1	¼	0	1	¼
Potash ration	¼	¼	1	½	¼
Plat No	**15**	**24**	**22**	**27**	**36**
Nitrogen	....	....	....	3.92	4.19
Pure ash and insol. matter	15.27	11.46	13.24	....	....
Silica and insol. matter	1.44	.91	1.37	.75	1.38
Carbon dioxid	2.52	1.88	1.90	....	....
Phosphoric acid	1.26	.98	1.03	.89	1.00
Sulfuric acid	1.95	1.60	....	....	....
Potassium oxid	2.13	2.88	4.54	3.21	2.54
Sodium oxid	5.05	2.37	1.46	2.31	2.88
Calcium oxid	1.26	1.32	1.31	1.36	1.45
Magnesium oxid	.69	.60	.62	.64	.69
Yield, green, pounds	293	214	234	212	149

NORBITON GIANT BEET (ROOTS), 1899.

	Limed Chlorids.			Limed Carbonates.		
Soda ration	1	½	0	1	½	0
Potash ration	½	½	1	½	½	1
Plat No	15	24	32	39	48	46
Nitrogen	1.75	1.63	....	2.20	2.23	....
Pure ash and insol. matter	8.81	6.27	8.61	8.92	7.00	7.07
Silica and insol. matter	....	....	.49	....	....	.56
Carbon dioxid	2.08	1.63	1.99	3.33	2.31	2.47
Phosphoric acid	.32	.24	.33	.39	.37	.35
Sulfuric acid	.31	.30	....	.40	.39	....
Potassium oxid	.84	1.24	3.65	.81	1.10	3.69
Sodium oxid	4.63	2.65	1.71	5.10	2.92	1.06
Calcium oxid	.26	.24	.26	.29	.25	.27
Magnesium oxid	.50	.56	.51	.48	.74	.47
Ferric and aluminic oxid	.10	.12	....	.14	.15	....
Yield, green, pounds	682	421	689	601	299	797

CARROT (ROOTS), 1899.

	Limed Chlorids.		Limed Carbonates.	
Soda ration	1	½	1	½
Potash ration	½	½	½	½
Plat No	15	24	39	48
Nitrogen	2.73	2.58	2.93	3.02
Crude ash	....	....	12.14	11.77
Silica and insol. matter	.51	.50	.57	.41
Phosphoric acid	1.20	1.03	1.09	1.07
Potassium oxid	2.11	2.09	1.30	2.36
Sodium oxid	3.77	3.00	3.88	2.89
Calcium oxid	.74	.78	.68	.70
Magnesium oxid	.32	.39	.35	.41
Yield, green, pounds	483	343	483	373

CHICORY (ROOTS), 1899.

	Limed Chlorids.			Limed Carbonates.		
Soda ration	1	½	0	1	½	0
Potash ration	¼	¼	1	¼	¼	1
Plat No	15	24	22	39	48	46
Pure ash and insol. matter	3.49	2.99	3.47	3.21	3.13	3.32
Silica and insol. matter	.26	.28	.27	.18	.28	.23
Carbon dioxid	.50	.33	.55	.50	.35	.72
Phosphoric acid	.48	.49	.45	.59	.56	.46
Sulfuric acid	.20	.23	....	.25	.28	....
Potassium oxid	.62	.48	1.42	.37	.45	1.43
Sodium oxid	1.01	.80	.37	1.04	.81	.35
Calcium oxid	.24	.22	.22	.26	.25	.24
Magnesium oxid	.25	.25	.18	.32	.32	.18
Ferric and aluminic oxids	.06	.06	....	.04	.04	....
Yield, green, pounds	189	200	312	205	234	256

WHITE STRASBURG RADISH (ROOTS), 1901.

	Unlimed Chlorids.	
Soda ration	1	½
Potash ration	¼	¼
Plat No	3	12
Nitrogen	3.20	3.54
Crude ash	19.65	18.53
Silica and insol. matter	.30	.21
Phosphoric acid	1.08	1.08
Potassium oxid	6.03	5.42
Sodium oxid	3.55	3.09
Calcium oxid	.90	1.13
Magnesium oxid	.53	.65
Yield, green, pounds	216	234

White Strasburg Radish (Roots), 1901.

	Limed Chlorids.		
Soda ration	¾	½	0
Potash ration	1	1	1
Plat No	**19**	**20**	**22**
Phosphoric acid	1.06	1.09	1.03
Potassium oxid	11.05	9.81	9.41
Sodium oxid	1.40	1.95	1.43
Calcium oxid	1.00	1.13	1.10
Magnesium oxid	.53	.66	.64
Yield, green, pounds	243	261	248

White Strasburg Radish (Roots), 1901.

	Unlimed Carbonates.		
Soda ration	¾	½	0
Potash ration	1	1	1
Plat No	**31**	**32**	**34**
Phosphoric acid	1.12	1.15	1.09
Potassium oxid	11.55	10.73	10.66
Sodium oxid	1.65	1.52	.91
Calcium oxid	.84	.95	.96
Magnesium oxid	.50	.59	.57
Yield, green, pounds	279	291	288

White Strasburg Radish (Roots), 1901.

	Limed Carbonates.		
Soda ration	¾	½	0
Potash ration	1	1	1
Plat No	**43**	**44**	**46**
Phosphoric acid	1.09	1.00	.92
Potassium oxid	10.00	9.21	9.42
Sodium oxid	1.60	1.56	.97
Calcium oxid	.89	.86	1.08
Magnesium oxid	.57	.51	.58
Yield, green, pounds	243	252	228

CHICORY (ROOTS). 1901.

	Limed Chlorids.		Limed Carbonates.	
Soda ration	1	¼	1	¼
Potash ration	¼	¼	¼	¼
Plat No	**15**	**24**	**39**	**48**
Nitrogen	1.12	1.03	1.19	1.14
Pure ash and insoluble matter	3.33	2.95	2.82	3.01
Carbon dioxid	.50	.46	.91	.41
Phosphoric acid	.53	.43	.48	.49
Sulfuric acid	.21	.22	.23	.24
Potassium oxid	.62	.63	.50	.55
Sodium oxid	1.18	.96	1.19	.84
Calcium oxid	.23	.22	.24	.21
Magnesium oxid	.24	.24	.27	.26
Yield, green, pounds	225	194	117	113

CHICORY (ROOTS), 1901.

	Limed Chlorids.		
Soda ration	¾	½	0
Potash ration	1	1	1
Plat No	**19**	**20**	**22**
Phosphoric acid	.44	.42	.43
Potassium oxid	1.97	1.90	1.82
Sodium oxid	.52	.72	.67
Calcium oxid	.24	.24	.24
Magnesium oxid	.16	.17	.17
Yield, green, pounds	243	243	243

Chicory (Roots), 1901.

	Unlimed Carbonates.		
Soda ration	¾	½	0
Potash ration	1	1	1
Plat No.	**31**	**32**	**34**
Nitrogen	.96	.95	.95
Phosphoric acid	.40	.41	.39
Potassium oxid	2.16	1.89	2.02
Sodium oxid	.52	.51	.34
Calcium oxid	.24	.24	.23
Magnesium oxid	.16	.15	.17
Yield, green, pounds	194	180	162

Chicory (Tops), 1901.

	Limed Carbonates.	
Soda ration	1	¼
Potash ration	¼	¼
Plat No.	**39**	**48**
Crude ash	13.79	13.14
Silica and insol. matter	.77	.76
Phosphoric acid	.56	.51
Potassium oxid	.97	.76
Sodium oxid	3.84	2.29
Calcium oxid	2.22	2.71
Magnesium oxid	1.11	1.81

CARROT (ROOTS), 1901.

	Limed Chlorids.		Limed Carbonates.	
Soda ration	1	½	1	½
Potash ration	½	½	½	½
Plat No	**15**	**24**	**39**	**48**
Nitrogen	1.98	2.37	2.49	2.09
Crude ash	8.32	8.17	9.32	6.69
Silica and insol. matter	.06	.04	.08	.08
Phosphoric acid	.95	.93	1.04	.77
Potassium oxid	1.45	1.50	1.29	1.22
Sodium oxid	2.54	1.98	3.00	1.71
Calcium oxid	.51	.50	.51	.50
Magnesium oxid	.27	.32	.35	.30
Yield, green, pounds	313	315	306	315

CARROT (TOPS), 1901.

	Limed Carbonates.	
Soda ration	1	½
Potash ration	½	½
Plat No	**39**	**48**
Nitrogen	3.08	2.87
Crude ash	14.63	11.89
Silica and insol. matter	.92	.67
Phosphoric acid	.80	.70
Potassium oxid	1.00	1.53
Sodium oxid	4.76	2.17
Calcium oxid	1.54	1.87
Magnesium oxid	.89	.96

White Strasburg Radish (Roots), 1905.

	Once-Limed Chlorids.			
Soda ration	1	¼	1	¾
Potash ration	¼	¼	¾	¾
Plat No	**3**	**12**	**1**	**11**
Nitrogen	3.50	3.84	3.47	3.65
Phosphoric acid	1.10	1.07	.97	1.03
Potassium oxid	3.17	3.22	6.34	6.13
Sodium oxid	4.08	2.99	3.16	2.99
Calcium oxid	1.42	1.69	1.21	1.31
Magnesium oxid,	.69	.79	.44	.71
Yield, green, pounds	456	398	550	557

White Strasburg Radish (Roots), 1905.

	Once-limed Chlorids.			
Soda ration	1	½	0	1
Potash ration	1	1	1	0
Plat No	**5**	**8**	**10**	**4**
Nitrogen	3.46	3.52	3.51	4.66
Phosphoric acid	1.02	1.06	1.08	1.24
Potassium oxid	6.75	7.72	6.62	1.95
Sodium oxid	2.73	2.34	1.94	5.43
Calcium oxid	1.00	1.18	1.12	1.55
Magnesium oxid	.76	.58	.83	1.03
Yield, green, pounds	574	542	522	274

WHITE STRASBURG RADISH (ROOTS), 1905.

	Thrice-limed Chlorids.				
Soda ration	1	¼	½	0	¾
Potash ration	¼	¼	1	1	¾
Plat No	**15**	**24**	**20**	**22**	**23**
Nitrogen	4.11	4.03	3.94	3.85	3.76
Phosphoric acid	1.08	.98	1.02	1.02	1.00
Potassium oxid	3.54	2.42	6.67	6.86	5.81
Sodium oxid	4.44	3.50	2.66	2.02	2.85
Calcium oxid	1.59	1.87	1.52	1.28	1.53
Magnesium oxid	.78	.83	.73	.95	.59
Yield, green, pounds	438	324	553	522	498

WHITE STRASBURG RADISH (ROOTS), 1905.

	Once-limed Carbonates.					
Soda ration	1	¼	½	0	1	¾
Potash ration	¼	¼	1	1	¾	¾
Plat No	**27**	**36**	**32**	**34**	**25**	**35**
Nitrogen	4.10	3.76	3.69	3.60	3.77	3.65
Phosphoric acid	1.26	1.15	1.19	1.17	1.16	1.11
Potassium oxid	2.58	2.95	6.19	6.33	5.52	5.03
Sodium oxid	4.11	2.95	2.24	1.71	2.88	2.74
Calcium oxid	1.58	1.66	1.23	1.03	1.20	1.08
Magnesium oxid	.78	.80	.62	.85	.64	.70
Yield, green, pounds	400	372	555	548	556	553

White Strasburg Radish (Roots), 1905.

	Thrice-limed Carbonates.				
Soda ration	1	¼	1	0	¾
Potash ration	¼	¼	1	1	¾
Plat No	**39**	**48**	**41**	**46**	**47**
Nitrogen	3.87	3.87	3.49	3.77	3.82
Phosphoric acid	1.16	1.03	1.09	1.06	1.12
Potassium oxid	2.60	3.21	5.32	6.05	5.11
Sodium oxid	4.04	2.90	2.64	2.27	2.75
Calcium oxid	1.52	1.67	1.24	1.30	1.32
Magnesium oxid	.76	.80	.79	.85	.65
Yield, green, pounds	398	375	532	508	514

White Strasburg Radish, 1905.

	Soda ration, 1; and Potash ration, ¾. Twice-limed Chlorids. Plat No. 13.		Twice-limed Carbonates. Plat No. 37	
	Roots.	*Tops.*	*Roots.*	*Tops.*
Nitrogen	3.88	4.69	3.66	4.93
Phosphoric acid	1.05	1.17	1.01	1.26
Potassium oxid	6.54	3.98	5.43	3.07
Sodium oxid	2.66	2.99	2.75	2.62
Calcium oxid	1.34	4.77	1.37	4.09
Magnesium oxid	.66	.95	.59	.78
Yield, green, pounds	547	520	555	527

STRAP-LEAFED, FLAT TURNIP, 1905.

	Once-limed Chlorids.					
Soda ration	1	½	1	¼	1	0
Potash ration	½	½	¼	¼	¾	1
Plat No.	2	6	3	12	1	10
Nitrogen	2.80	2.41	2.90	3.01	2.72	2.37
Phosphoric acid	1.42	1.29	1.39	1.32	1.28	1.33
Potassium oxid	3.05	2.60	1.99	2.07	3.87	3.93
Sodium oxid	2.42	1.91	3.09	2.14	1.97	1.04
Calcium oxid	.80	.83	.87	.99	.95	.80
Magnesium oxid	.35	.37	.31	.40	.34	.47
Yield, green, pounds	402	390	373	240	379	417

STRAP-LEAFED, FLAT TURNIP, 1905.

	Thrice-limed Chlorids.				
Soda ration	1		½	1	¼
Potash ration	½		½	¼	¼
Plat No.	14		18	15	24
	Tops.	*Roots.*	*Roots.*	*Roots.*	*Roots.*
Nitrogen	3.28	2.46	2.64	3.08	3.13
Phosphoric acid	1.31	1.26	1.26	1.35	1.29
Potassium oxid	2.28	2.72	2.48	1.96	1.79
Sodium oxid	2.44	2.49	2.30	3.59	2.94
Calcium oxid	5.29	.93	1.00	.99	1.17
Magnesium oxid	1.04	.36	.35	.37	.38
Yield, green, pounds	647	377	340	294	192

STRAP-LEAFED, FLAT TURNIP, 1905.

	Thrice-limed Chlorids.					
Soda ration	1	½	0		1	¾
Potash ration	1	1	1		¾	¾
Plat No	**17**	**20**	**22**		**13**	**23**
	Roots.	*Roots.*	*Tops.*	*Roots.*	*Roots.*	*Roots.*
Nitrogen	2.32	2.22	3.25	2.55	2.24	2.51
Phosphoric acid	1.31	1.28	1.33	1.28	1.23	1.33
Potassium oxid	3.82	3.94	3.28	3.69	3.15	3.33
Sodium oxid	1.71	1.38	1.45	1.23	1.70	2.09
Calcium oxid	.91	1.03	4.98	.98	.90	1.02
Magnesium oxid	.36	.41	1.58	.50	.38	.33
Yield, green, pounds	382	392	640	369	371	376

STRAP-LEAFED, FLAT TURNIP (ROOTS), 1905.

	Once-limed Carbonates.			
Soda ration	1	½	1	¼
Potash ration	½	½	¼	¼
Plat No	**26**	**30**	**27**	**36**
Nitrogen	2.54	2.77	3.33	3.07
Phosphoric acid	1.42	1.41	1.47	1.45
Potassium oxid	2.48	2.29	1.68	1.92
Sodium oxid	2.39	2.12	3.46	2.45
Calcium oxid	.87	1.00	.90	1.04
Magnesium oxid	.36	.36	.38	.40
Yield, green, pounds	385	311	269	227

SRAP–LEAFED, FLAT TURNIP (ROOTS), 1905.

	Once-limed Carbonates.			
Soda ration	1	½	0	1
Potash ration	1	1	1	¾
Plat No	**29**	**32**	**34**	**25**
Nitrogen	2.40	2.22	2.53	2.61
Phosphoric acid	1.40	1.41	1.40	1.46
Potassium oxid	3.45	3.53	3.53	2.80
Sodium oxid	1.66	1.47	1.26	1.99
Calcium oxid	.90	.81	.78	.84
Magnesium oxid	.35	.34	.46	.38
Yield, green, pounds	358	420	414	389

STRAP–LEAFED, FLAT TURNIP (ROOTS), 1905.

	Thrice-limed Carbonates.			
Soda ration	1	¼	½	¾
Potash ration	¼	¼	½	¾
Plat No	**39**	**48**	**42**	**47**
Nitrogen	2.67	3.28	2.70	2.60
Phosphoric acid	1.39	1.30	1.38	1.41
Potassium oxid	2.94	2.03	2.62	3.25
Sodium oxid	2.13	2.47	2.04	1.72
Calcium oxid	.89	1.15	.90	.88
Magnesium oxid	.39	.41	.40	.37
Yield, green, pounds	372	246	343	404

Strap-Leafed, Flat Turnip (Roots), 1905.

	Thrice-limed Carbonates.			
Soda ration	1	½	0	1
Potash ration	1	1	1	¾
Plat No.	**41**	**44**	**46**	**37**
Nitrogen	2.45	2.59	2.52	2.42
Phosphoric acid	1.42	1.43	1.31	1.38
Potassium oxid	3.50	3.88	3.49	3.22
Sodium oxid	1.75	1.38	1.27	1.90
Calcium oxid	.74	.89	.88	.92
Magnesium oxid	.46	.41	.42	.38
Yield, green, pounds	394	399	384	392

REPORT OF METEOROLOGIST.

NATHANIEL HELME.

SUMMARY, JULY 1, 1905, TO JUNE 30, 1906.

Temperature.

Maximum................	92°	July 19, 1905.
Minimum................	—3°	January 10, 1906.
Highest daily mean.......	80°	July 18, and 19, 1905.
Lowest daily mean.........	9°	February 3, 1906.
Highest monthly mean....	70.3°	July, 1905.
Lowest monthly mean.....	28.6°	February, 1906.
Mean temperature of the year.................	48.4°	

Precipitation. (Rain and melted Snow.)

Total for the year...............53.57 inches.
Largest monthly................. 6.34 inches, March, 1906.
Least monthly................. 1.75 inches, October, 1905.
Greatest in any 24 consecutive hours........................ 2.21 inches, Sept. 4, 1905.
Snowfall (unmelted).............27 inches, December, 3 inches; January, 9 inches; February, 4 inches; March, 11 inches.

Prevailing Winds.

Southwest; July, August, 1905; May, June, 1906. West; September, October, November, December, 1905; January, February, March, 1906. Northwest; April, 1906.

Weather.

Number of clear days in the year........................... 175
Partly cloudy days.. 99
Cloudy days... 91
Days with .01 inch or more of precipitation................. 97

Summary by months, 1905–1906.

MONTHS.	Maximum Temperature.	Minimum Temperature.	Mean Temperature.	Precipitation (rain and melted snow), inches.	Snowfall (unmelted).	Clear Days.	Partly Cloudy Days.	Cloudy Days.	Days with .01 inch or more of Precipitation.	Prevailing Winds.
1905.										
July..............	92°	50°	70.3°	3.71	......	15	7	9	8	S. W.
August...........	87°	45°	66.3°	4.66	......	15	6	10	11	S. W.
September........	79°	33°	60.4°	5.86	......	16	3	11	11	W.
October...........	79°	27°	51.8°	1.75	......	20	6	5	5	W.
November.........	63°	12°	39.6°	4.23	......	18	9	3	6	W.
December.........	58°	9°	33.2°	5.71	3	15	7	9	6	W.
1906.										
January...........	62°	—3°	33°	5.16	9	13	11	7	12	W.
February..........	56°	—2°	28.6°	4.71	4	12	9	7	6	W.
March.............	53°	5°	31.2°	6.34	11	13	9	9	11	W.
April..............	72°	20°	45.4°	3.72	......	12	12	6	7	N. W.
May...............	86°	32°	56.4°	4.56	......	16	9	6	8	S. W.
June..............	87°	42°	64.4°	3.16	......	10	11	9	6	S. W.
Total.........	......	......	......	53.57	27	175	99	91	97	......
Mean.......	72.8°	22.5°	48.4°	......	......	......	......	......	......	......

The principal characteristics of the weather for each month were as follows:

The mean temperature of July and the precipitation were both

slightly above the average, and the weather was favorable for gathering the hay crop.

The mean temperature of August was slightly below and the rainfall above, the average. The weather of the month was about the normal, the precipitation being well distributed.

The rainfall for September was above, and the temperature below, the average. There was killing frost on low land on the morning of the 27th.

The precipitation for October was below the average, and the least for the month since 1897. Fine weather for harvesting and out-door labor prevailed during the month. There were killing frosts on the 23rd, 26th, 27th and 30th. The mean temperature was slightly below the average.

The weather for November was unusually pleasant there being but three cloudy days in the month. The temperature and precipitation were each below the average.

The mean temperature of December was ten degrees higher than that of the same month in 1904. The ground was bare of snow for the greater part of the time and at the end of the month there was practically no frost in the ground.

It was the warmest January since 1890 and the maximum temperature was the highest for the month on our record. There was no frost in the ground at the end of the month.

With the exception of three days, the ground was bare of snow during the whole month of February. Robins and blue birds were seen, daffodils were in bud and willows were already in bloom by the latter part of the month.

The mean temperature of March was less than that of either December or January. It was below the average for the month for seventeen years, and but twice during that period has it been lower,

viz. in 1896 (30.6°) and 1900 (29.4°). The precipitation was above the average while the snowfall was greater than in any one of the winter months. The minimum temperature of 6° on the 24th, was something unusual for so late a date in the month.

The mean temperature of April was slightly above, and the precipitation below, the average for the month. There were killing frost on the 24th and 26th.

The precipitation and temperature of May were each above the average. There was killing frost on the 11th and on low land on the 22nd.

The record for June shows a mean temperature above, and precipitation below, the average. The month ended with one of the severest thunder storms that has been experienced here for several years, considerable damage being done by lightning.

The following tables show the maximum, minimum, and mean temperature, character of day, precipitation and prevailing wind for each day in the year; and also a general summary from January 1, 1890, to June 30, 1906, inclusive.

WEATHER SUMMARY FOR JULY, 1905.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	77	54	65.5	....	S. W.	Cloudy.
2	68	61	64.5	.11	S.	Cloudy.
3	81	61	71	....	Variable.	Clear.
4	88	59	73.5	....	W.	Clear.
5	70	57	63.5	....	S.	Cloudy.
6	75	59	67	....	S.	Fair.
7	80	61	70.5	....	S. W.	Cloudy.
8	83	63	73	....	S. E.	Fair.
9	85	64	74.5	....	S. W.	Clear.
10	89	66	77.5	....	W.	Clear.
11	87	67	77	....	S. W.	Clear.
12	85	68	76.5	1.38	S. W.	Fair.
13	84	70	77	....	S. W.	Fair.
14	83	67	75	.17	S. W.	Fair.
15	82	61	71.5	....	W.	Clear.
16	78	54	66	....	S. W.	Clear.
17	88	63	75.5	.48	S. W.	Fair.
18	91	69	80	....	S. W	Clear.
19	92	68	80	Trace.	S. W.	Clear.
20	85	63	74	....	W.	Clear.
21	82	59	70.5	....	W.	Clear
22	79	56	67.5	....	S. W.	Fair.
23	65	58	61.5	.46	N. E.	Cloudy.
24	70	54	62	.36	S.	Cloudy.
25	78	56	67	....	W.	Clear.
26	77	51	64	....	W.	Clear.
27	80	50	65	....	W.	Clear.
28	82	56	69	....	S.	Clear.
29	74	63	68.5	.27	E.	Cloudy.
30	76	63	69.5	.48	Variable.	Cloudy.
31	67	58	62.5	....	N. W.	Cloudy.
Sum........	2,481	1,879	2,180	3.71	....	....
Mean.......	80	60.6	70.3	....	....	....

Maximum temperature........92°. **Mean temperature........70.3°.**
Minimum temperature........50°. **Prevailing wind..........S. W.**

WEATHER SUMMARY FOR AUGUST, 1905.

	Temperature			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	64°	55°	59.5°	.13	N.	Cloudy.
2	79	52	65.5	....	W.	Clear.
3	80	55	67.5	....	N. W.	Clear.
4	79	56	67.5	....	W.	Clear.
5	80	62	71	....	S.	Clear.
6	81	61	71	....	S. W.	Clear.
7	86	66	76	....	S. W.	Clear.
8	82	61	71.5	....	S. W.	Cloudy.
9	78	67	72.5	.58	S. W.	Rainy.
10	79	66	72.5	....	S. W.	Cloudy.
11	83	70	76.5	....	S. W.	Fair.
12	83	69	76	.08	S. W.	Cloudy.
13	82	65	73.5	.40	Variable.	Cloudy.
14	73	60	66.5	....	N. E.	Fair.
15	62	54	58	1.42	N. E.	Rainy.
16	58	53	55.5	.36	N. E.	Cloudy.
17	72	46	59	....	Variable.	Clear.
18	71	46	58.5	....	N. E.	Clear.
19	69	49	59	....	N. E.	Clear.
20	73	49	61	....	S.	Fair.
21	80	58	69	....	S. W.	Clear.
22	82	60	71	....	S. W.	Clear.
23	87	63	75	....	N. W.	Clear.
24	85	57	71	.15	S. W.	Fair.
25	72	58	65	.33	N. E.	Cloudy.
26	74	54	64	....	N. E.	Fair.
27	66	46	56	.16	N. E.	Clear.
28	72	45	58.5	....	N. W.	Clear.
29	75	54	64.5	.18	N. W.	Fair.
30	73	54	63.5	.87	S. W.	Cloudy.
31	66	53	59.5	....	N.	Clear.
Sum........	2,346	1,764	2,055	4.66	....	....
Mean.......	75.7	56.9	66.3	....	....	....

Maximum temperature........87°. Mean temperature........ 66.3°
Minimum temperature........45°. Prevailing wind............S. W.

WEATHER SUMMARY FOR SEPTEMBER, 1905.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	68°	49°	58.5°	Trace.	S.	Fair.
2	72	54	63	.02	S.	Cloudy.
3	65	60	62.5	2.17	S. E.	Rainy.
4	72	65	68.5	2.21	S.	Rainy.
5	77	59	68	....	S. W.	Fair.
6	73	53	63	.03	S. W.	Clear.
7	74	53	63.5	....	W.	Clear.
8	72	51	61.5	....	Variable.	Clear.
9	78	52	65	....	W.	Clear.
10	79	53	66	....	S. W.	Clear.
11	69	55	62	.20	S.	Cloudy.
12	66	57	61.5	.82	S. E.	Rainy.
13	70	55	62.5	....	N. W.	Cloudy.
14	63	41	52	....	N. W.	Clear.
15	64	38	51	....	Variable.	Fair.
16	65	48	56.5	....	S.	Cloudy.
17	70	58	64	.03	S. E.	Cloudy.
18	72	57	64.5	.10	E.	Cloudy.
19	68	60	64	.15	N. E.	Cloudy.
20	66	59	62.5	.13	S. E.	Rain and fog.
21	72	54	63	....	N. W.	Clear.
22	79	50	64.5	....	S. W.	Clear.
23	71	50	60.5	....	W.	Clear.
24	65	43	54	....	W.	Clear.
25	62	42	52	....	W.	Clear.
26	58	34	46	....	W.	Clear.
27	63	33	48	....	W.	Clear.
28	72	44	58	....	S. W.	Clear.
29	70	49	59.5	....	S. W.	Clear.
30	79	53	66	....	W.	Clear.
Sum........	2,094	1,529	1,811.5	5.86	....	....
Mean.......	69.8	51	60.4	....	....	....

Maximum temperature........79°. Mean temperature.........60.4°.
Minimum temperature........33°. Prevailing wind,...........W.

WEATHER SUMMARY FOR OCTOBER, 1905.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	69°	50°	59.5°	....	Variable.	Clear.
2	64	50	57	....	S. E.	Cloudy.
3	75	55	65	.09	W.	Fair.
4	78	46	62	....	W.	Clear.
5	79	55	67	....	W.	Clear.
6	62	42	52	....	N.	Clear.
7	62	36	49	....	Variable.	Clear.
8	67	37	52	....	W.	Clear.
9	77	50	63.5	....	Variable.	Clear.
10	61	41	51	....	S.	Clear.
11	56	47	51.5	.39	E.	Cloudy.
12	62	40	51	....	W.	Clear.
13	60	32	56	....	W.	Clear.
14	68	42	55	....	W.	Clear.
15	77	47	62	....	S. W.	Clear.
16	73	54	63.5	....	S. W.	Fair.
17	64	39	51.5	....	S. W.	Clear.
18	66	42	54	....	S. E.	Fair.
19	73	60	66.5	.04	S. E.	Cloudy.
20	61	54	57.5	1.15	Variable.	Rainy.
21	54	34	44	....	N. W.	Clear.
22	53	27	40	....	W.	Fair.
23	53	32	42.5	....	W.	Clear.
24	60	33	46.5	.08	S. W.	Fair.
25	54	41	47.5	....	W.	Cloudy.
26	47	29	38	....	N.	Clear.
27	52	27	39.5	....	N.	Clear.
28	59	33	46	....	N. E.	Clear.
29	50	33	41.5	....	N. E.	Clear.
30	51	29	40	....	N. E.	Clear.
31	54	32	43	....	S. E.	Fair.
Sum........	1,941	1,269	1,605	1.75	....	....
Mean........	62.6	40.9	51.8	....	....	....

Maximum temperature........79°.
Minimum temperature........27°.
Mean temperature........51.8°.
Prevailing wind......... west.

WEATHER SUMMARY FOR NOVEMBER, 1905.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	63°	35°	49°	....	S. W.	Fair.
2	46	23	34.5	....	W.	Clear.
3	52	27	39.5	....	S. E.	Fair.
4	52	34	43	1.34	N. W.	Clear.
5	54	31	42.5	....	W.	Fair.
6	53	39	46	.26	Variable.	Fair.
7	52	32	42	....	N. E.	Fair.
8	48	32	40	....	W.	Fair.
9	48	26	37	....	W.	Clear.
10	45	24	34.5	....	W.	Clear.
11	48	23	35.5	....	S. W.	Clear.
12	55	35	45	....	S. W.	Clear.
13	57	38	47.5	Trace.	S. W.	Fair.
14	42	12	27	....	N. W.	Clear.
15	48	15	31.5	.30	S.	Fair.
16	48	38	43	....	W.	Cloudy.
17	43	31	37	....	W.	Fair.
18	48	30	39	....	W.	Clear.
19	48	24	36	....	N. W.	Clear.
20	38	19	28.5	....	N.	Clear.
21	49	23	60.5	....	W.	Clear.
22	53	23	38	....	W.	Clear.
23	57	29	43	....	W.	Clear.
24	58	37	47.5	....	S. W.	Clear.
25	63	39	51	.05	W.	Clear.
26	52	32	42	....	N. E.	Clear.
27	47	28	37.5	....	W.	Clear.
28	48	22	35	.03	S. E.	Cloudy.
29	55	45	50	2.25	S. E.	Rainy.
30	58	14	36	....	N. W.	Clear.
Sum.........	1,518	860	1,189	4.23	....	....
Mean.......	50.6	28.7	39.6	....	....	....

Maximum temperature.........63°.
Minimum temperature.........12°.
Mean temperature.......39.6°.
Prevailing wind..........west.

WEATHER SUMMARY FOR DECEMBER, 1905.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	33°	9°	21°	....	N. W.	Clear.
2	49	18	33.5	Trace.	S.	Cloudy.
3	58	40	49	1.92	S.	Rainy.
4	40	23	31.5	....	W.	Clear.
5	33	15	24	....	W.	Clear.
6	41	18	29.5	....	W.	Fair.
7	45	24	34.5	....	W.	Clear.
8	51	28	39.5	....	W.	Clear.
9	38	26	32	.05	N. E.	Cloudy.
10	36	19	27.5	1.00	N. W.	Fair.
11	35	10	22.5	....	W.	Cloudy.
12	35	22	28.5	....	N. E.	Fair.
13	45	21	33	....	W.	Fair.
14	35	19	27	....	W.	Clear.
15	22	9	15.5	....	N. E.	Cloudy.
16	33	17	25	....	N. E.	Fair.
17	33	25	29	.01	N.	Cloudy.
18	52	22	37	....	W.	Clear.
19	43	26	34.5	....	Variable.	Fair.
20	50	30	40	....	N. W.	Clear.
21	52	30	41	1.70	S. W.	Cloudy.
22	52	38	45	....	W.	Clear.
23	47	32	39.5	.15	S. W.	Cloudy.
24	40	24	32	....	W.	Clear.
25	38	18	28	....	W.	Clear.
26	40	18	29	....	W.	Clear.
27	47	28	37.5	....	W.	Clear.
28	57	28	42.5	....	W.	Clear.
29	54	35	44.5	.88	S.	Rainy.
30	49	33	41	....	W.	Clear.
31	43	25	34	....	W.	Fair.
Sum........	1,326	730	1,028	5.71	....	....
Mean.......	42.8	23.6	33.2	....	....	....

Maximum temperature.........58°. Mean temperature........33.2°.
Minimum temperature......... 9°. Prevailing wind...........west.

WEATHER SUMMARY FOR JANUARY, 1906.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	39°	18°	28.5°	....	N. W.	Clear.
2	35	19	27	....	W.	Fair.
3	32	19	25.5	.09	N. E.	Fair.
4	53	31	42	1.85	S.	Cloudy.
5	45	30	37.5	....	W.	Fair.
6	40	27	33.5	....	W.	Clear.
7	35	19	27	.05	W.	Clear.
8	27	17	22	.10	E.	Cloudy.
9	25	9	17	.25	W.	Clear.
10	26	-3	11.5	....	W.	Clear.
11	38	16	27	....	S.	Fair.
12	54	30	42	.03	Variable.	Cloudy.
13	37	27	32	....	N. E.	Cloudy.
14	36	24	30	.90	N.	Cloudy.
15	37	18	27.5	....	Variable.	Fair.
16	48	33	40.5	.96	S.	Fair.
17	38	26	32	....	W.	Clear.
18	42	24	33	.28	S. W.	Fair.
19	41	25	33	.03	W.	Clear.
20	42	24	33	....	S. E.	Cloudy.
21	58	41	49.5	....	S. W.	Fair.
22	60	40	50	....	S. W.	Clear.
23	62	47	54.5	....	S.	Cloudy.
24	53	28	40.5	.36	N. W.	Fair.
25	29	14	21.5	....	N.	Fair.
26	36	16	26	....	N. E.	Clear.
27	48	25	36.5	....	E.	Clear.
28	47	33	40	.26	N.	Fair.
29	38	17	27.5	....	N.	Clear.
30	46	20	33	....	S. W.	Clear.
31	52	33	42.5	....	S.	Clear.
Sum.......	1,299	747	1,023	5.16	....	....
Mean.......	41.9	24.1	33	....	....	....

Maximum temperature.........62°. **Mean temperature........33°.**
Minimum temperature.........-3°. **Prevailing wind...........west.**

WEATHER SUMMARY FOR FEBRUARY, 1906.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	45°	27°	36°	....	W.	Fair.
2	35	3	19	....	N. W.	Clear.
3	20	—2	9	....	W.	Clear.
4	41	10	25.5	....	S. W.	Cloudy.
5	48	19	33.5	....	S. W.	Fair.
6	22	4	13	....	N.	Fair.
7	22	10	16	....	N.	Fair.
8	31	6	18.5	....	E.	Fair.
9	37	24	30.5	1.78	N. E.	Rain & Snow
10	35	20	27.5	....	W.	Clear.
11	29	10	19.5	....	N. W.	Clear.
12	39	22	30.5	....	N. E.	Cloudy.
13	39	33	36	.43	N. E	Rain & fog.
14	48	32	40	.02	Variable.	Cloudy.
15	35	14	24.5	....	N. W.	Fair.
16	35	8	21.5	....	N. W.	Clear.
17	38	13	25.5	....	E.	Clear.
18	37	21	29	.05	S. W.	Fair.
19	44	25	34.5	....	W.	Fair.
20	49	28	38.5	....	S. W.	Clear.
21	56	35	45.5	2.07	S.	Rainy.
22	51	29	40	....	N. W.	Clear.
23	43	25	34	....	Variable.	Clear.
24	52	25	38.5	....	S. W.	Clear.
25	36	28	32	.36	S. E.	Cloudy.
26	47	27	37	....	N. W.	Clear.
27	39	18	28.5	....	N.	Fair.
28	25	9	17	....	N. W.	Clear.
Sum........	1,078	523	800.5	4.71	....	....
Mean.......	38.5	18.7	28.6	....	....	....

Maximum temperature.........56°.
Minimum temperature........—2°.
Mean temperature........28.6°.
Prevailing wind..........west.

WEATHER SUMMARY FOR MARCH, 1906.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	31°	5°	18°	....	W.	Clear.
2	41	14	27.5	....	W.	Clear.
3	47	26	36.5	.91	N. E.	Rainy.
4	52	35	43.5	1.25	W.	Cloudy.
5	46	26	36	....	N. W.	Clear.
6	39	17	28	....	S. E.	Clear.
7	46	22	34	....	S. W.	Fair.
8	48	33	40.5	.10	S. W.	Fair.
9	42	29	35.5	.37	N. W.	Rainy.
10	50	29	39.5	....	S. W.	Clear.
11	48	25	36.5	....	W.	Fair.
12	44	26	35	.18	N. W.	Fair.
13	32	10	21	....	Variable.	Fair.
14	31	16	23.5	....	N. E.	Fair.
15	30	12	21	1.00	N. E.	Rain & Snow.
16	41	12	26.5	....	N. W.	Clear.
17	33	16	24.5	....	N. W.	Clear.
18	33	12	22.5	....	N. W.	Clear.
19	37	16	26.5	1.10	E.	Rain & Snow
20	42	24	33	....	W.	Fair.
21	38	15	26.5	....	S. W.	Clear.
22	44	21	34.5	....	W.	Clear.
23	30	10	20	....	N. W.	Clear.
24	33	6	19.5	....	N.	Clear.
25	38	15	26.5	....	E.	Clear.
26	40	21	30.5	.11	E.	Rainy.
27	50	38	44	.31	S.	Rainy.
28	48	35	41.5	....	W.	Fair.
29	53	29	41	....	W.	Fair.
30	42	37	39.5	.92	N. E.	Rainy.
31	45	32	38.5	.09	N. W.	Cloudy.
Sum........	1,274	664	969	6.34	....	....
Mean.......	41.1	21.4	31.2	....	....	....

Maximum temperature.........53°.
Minimum temperature.......... 5°.
Mean temperature........31.2°.
Prevailing wind...........west.

WEATHER SUMMARY FOR APRIL, 1906.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	48°	20°	34°	....	N. W.	Clear.
2	43	22	32.5	....	N. W.	Clear.
3	50	23	36.5	....	S. W.	Clear.
4	62	27	44.5	....	S. W.	Fair.
5	62	38	50	....	W.	Fair.
6	48	37	42.5	.30	W.	Fair.
7	50	26	38	....	W.	Clear.
8	52	31	41.5	....	N.	Clear.
9	43	29	36	.45	N. E.	Rainy.
10	56	35	45.5	2.02	Variable.	Rainy.
11	57	35	46	....	N. W.	Fair.
12	54	39	46.5	....	N. W.	Fair.
13	55	32	43.5	....	W.	Clear.
14	52	34	43	....	S. E.	Cloudy.
15	53	46	49.5	.29	S. E.	Rainy.
16	59	42	50.5	....	N. W.	Fair.
17	62	35	48.5	....	W.	Clear.
18	68	39	53.5	....	S. W.	Clear.
19	62	35	48.5	....	S. E.	Fair.
20	58	39	48.5	....	S. E.	Fair.
21	72	41	56.5	....	S. W.	Fair.
22	62	43	52.5	.02	S. W.	Fair.
23	44	37	40.5	.26	N. E.	Rainy.
24	55	32	43.5	....	N. W.	Fair.
25	55	35	45	....	N. W.	Fair.
26	61	30	45.5	....	W.	Clear.
27	60	40	50	....	W.	Clear.
28	62	40	51	....	N. W.	Clear.
29	63	38	50.5	....	W.	Clear.
30	57	40	48.5	.38	S.	Rainy.
Sum........	1,685	1,040	1,362.5	3.72	....	....
Mean.......	56.2	34.7	45.4	....	....	....

Maximum temperature.........72°. Mean temperature........45.4°.
Minimum temperature.........20°. Prevailing wind...........northwest.

WEATHER SUMMARY FOR MAY, 1906.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	70°	42°	56°	....	W.	Clear.
2	58	41	49.5	.52	S.	Rainy.
3	69	48	58.5	....	W.	Fair.
4	58	38	48	....	S. W.	Clear.
5	73	48	60.5	....	S. W.	Clear.
6	67	51	59	Trace.	S.	Cloudy.
7	58	46	52	.88	N. W.	Cloudy.
8	61	42	51.5	....	N. W.	Clear.
9	60	39	49.5	.02	S.	Fair.
10	50	38	44	....	N. W.	Fair.
11	57	32	44.5	....	W.	Clear.
12	62	37	49.5	....	S. W.	Clear.
13	80	53	66.5	....	S. W.	Fair.
14	67	42	54.5	.34	Variable.	Fair.
15	60	38	49	....	Variable.	Clear.
16	79	38	58.5	....	S. W.	Clear.
17	76	51	63.5	....	S. W.	Fair.
18	86	58	72	....	S. W.	Clear.
19	86	58	72	....	W.	Clear.
20	69	45	57	....	W.	Clear.
21	60	38	49	....	S. W.	Clear.
22	65	37	51	....	S. W.	Clear.
23	72	42	57	....	S. W.	Clear.
24	79	51	65	.04	S. W.	Fair.
25	82	56	69	....	S. W.	Clear.
26	75	50	62.5	....	S. W.	Fair.
27	63	58	60.5	.13	S.	Cloudy.
28	60	44	52	2.15	N. E.	Rainy.
29	62	42	52	.48	N. W.	Fair.
30	68	41	54.5	....	N. W.	Clear.
31	70	50	60	....	S. W.	Cloudy.
Sum........	2,102	1,394	1,748	4.56	....	....
Mean.......	67.8	45	56.4	....	....	....

Maximum temperature.........86°. Mean temperature........56.4°.
Minimum temperature.........32°. Prevailing wind...........southwest.

WEATHER SUMMARY FOR JUNE, 1906.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	78°	50°	64°	....	S. W.	Cloudy.
2	75	56	65.5	....	S. W.	Cloudy.
3	77	54	65.5	....	W.	Clear.
4	73	51	62	....	S. W.	Clear.
5	77	52	64.5	....	S. W.	Fair.
6	77	57	67	.48	S. W.	Cloudy.
7	68	51	59.5	....	N. E.	Fair.
8	60	47	53.5	....	N. E.	Cloudy.
9	77	55	66	.21	S. W.	Cloudy.
10	82	59	70.5	....	W.	Clear.
11	72	52	62	....	N. W.	Fair.
12	65	42	53.5	....	Variable.	Clear.
13	72	47	59.5	....	Variable.	Clear.
14	78	50	64	....	W.	Clear.
15	83	50	66.5	....	S. E.	Clear.
16	60	52	56	1.37	E.	Rainy.
17	75	58	66.5	.35	E.	Cloudy.
18	60	56	58	.15	N. E.	Cloudy.
19	68	53	60.5	....	N. E.	Fair.
20	76	49	62.5	....	S. E.	Clear.
21	73	51	62	....	E.	Fair.
22	74	61	67.5	....	S. W.	Clear.
23	78	55	66.5	....	S. W.	Fair.
24	71	54	62.5	....	E.	Fair.
25	77	55	66	....	W.	Fair.
26	77	55	66	....	W.	Fair.
27	83	59	71	....	S. W.	Clear.
28	87	63	75	....	Variable.	Fair.
29	85	63	74	....	W.	Fair.
30	87	59	73	.60	W.	Fair.
Sum........	2,245	1,616	1,930.5 ~~1,390.5~~	3.16	....	....
Mean.......	74.8	53.9	64.4	....	....	....

Maximum temperature.........87°. Mean temperature........64.4°.
Minimum temperature.........42°. Prevailing wind...........southwest

SUMMARY, JANUARY 1, 1890, TO JUNE 30, 1906, INCLUSIVE.

	Maximum Temperature.	Minimum Temperature.	Mean Temperature.	Number of Clear Days.	Partly Cloudy Days.	Cloudy Days.	Days with .01 inch or more of Precipitation.	Total Precipitation, inches.
1890	91°	3°	48.3°	99	143	123	120	59.25
1891	94°	5°	49.4°	116	154	95	83	49.88
1892	92°	—1°	47.8°	147	116	103	89	42.56
1893	92°	—6°	46.5°	126	130	109	131	57.33
1894	93°	—9°	48.6°	110	130	125	114	48.19
1895	93°	—7°	48.2°	128	114	123	108	49.28
1896	93°	—11°	47.7°	131	112	123	109	49.87
1897	90°	—1°	48.3°	129	126	110	128	54.25
1898	95°	—4°	48.8°	110	114	141	131	72.21
1899, Jan. 1, to June 30	95°	—10°	42.1°	77	44	60	59	26.79
July 1, 1899, to June 30, 1900	90°	—5°	48.3°	141	113	111	102	51.67
July 1, 1900, to June 30, 1901	97°	—9°	48.4°	134	97	134	114	48.47
July 1, 1901, to June 30, 1902	93°	—1°	48°	138	116	111	109	53.14
July 1, 1902, to June 30, 1903	90°	—12°	48.3°	138	96	131	103	59.27
July 1, 1903, to June 30, 1904	93°	—16°	45.7°	156	107	103	118	50.06
July 1, 1904, to June 30, 1905	87°	—4°	45.3°	151	122	92	99	41.64
July 1, 1905, to June 30, 1906	92°	—3°	48.4°	175	99	91	97	53.57

Average temperature, 16½ years, 47.5°. Average precipitation, 16½ years, 52.57 inches.

REPORT OF THE TREASURER.

THE RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, *in account with the* UNITED STATES APPROPRIATION, 1905–1906.

1906.	DR.		
	To receipts from the treasurer of the United States as per appropriation for fiscal year ended June 30, 1906, as per act of Congress approved March 2, 1887		$15,000 00
1906.	CR.		
	By Salaries	$8,738 82	
	Labor	2,132 92	
	Publications	53 01	
	Postage and stationery	206 34	
	Freight and express	177 06	
	Heat, light, water, and power	478 51	
	Chemical supplies	40 58	
	Seeds, plants, and sundry supplies	286 71	
	Fertilizers	276 20	
	Feeding-stuffs	538 69	
	Library	439 75	
	Tools, implements, and machinery	485 13	
	Furniture and fixtures	131 49	
	Scientific apparatus	3 55	
	Live stock	212 70	
	Traveling expenses	211 35	
	Contingent expenses	15 00	
	Buildings and repairs	572 19	
			$15,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Rhode Island Agricultural Experiment Station for the fiscal year ended June 30, 1906; that we have found the same well kept and classified as above, and that the receipts for the

year from the treasurer of the United States are shown to have been $15,000, and the corresponding disbursements $15,000, for all of which proper vouchers are on file, and have been examined by us and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress approved March 2, 1887.

CHARLES DEAN KIMBALL,
R. S. BURLINGAME,
Auditors.

THE RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, *in account with the* UNITED STATES APPROPRIATION, 1905–1906.

1906. DR.

To receipts from the treasurer of the United States as per appropriation for fiscal year ended June 30, 1906, as per act of Congress approved March 16, 1906		$5,000 00

1906. CR.

By Salaries	$496 30	
Chemical supplies	143 26	
Seeds, plants, and sundry supplies	39 97	
Fertilizers	3 00	
Library	222 21	
Tools, implements, and machinery	531 20	
Scientific apparatus	835 95	
Traveling expenses	192 31	
Balance	2,535 80	
		$5,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Rhode Island Agricultural Experiment Station for the fiscal year ended June 30, 1906; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $5,000.00, and the corresponding disbursements $2,464.20; for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving $2,535.80 as balance on hand.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress approved March 16, 1906.

CHARLES DEAN KIMBALL,
R. S. BURLINGAME,
Auditors.

C. H. Coggeshall, *Treasurer, in account with the* Rhode Island Agricultural Experiment Station, *for the year ended June* 30, 1906.

1906.	Dr.	
	To Balance from last year	$3,216 91
	Station receipts	479 45
	Interest	106 88
		$3,803 24
1906.	Cr.	
	By Publications	$2 25
	Postage and stationery	24 54
	Seeds, plants, and sundry supplies	13 35
	Traveling expenses	4 69
	Contingent expenses	23 30
	Buildings and repairs	13 48
	Balance	3,721 63
		$3,803 24

This certifies that we, the undersigned, auditing committee of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts, have examined the account of C. H. Coggeshall, treasurer of the Rhode Island Agricultural Experiment Station, and find the same correct.

The total receipts were $3,803.24, and the total expenditures were $81.61, thus leaving a balance to new account of $3,721 63.

CHARLES DEAN KIMBALL,
R. S. BURLINGAME,
Auditors.

Directions for Binding the Bulletins and Reports of the Rhode Island Experiment Station.

Vol.	1–3,*	Bulletins	1–9,	Reports,	1–3,	1888–1890.
"	4,	"	10–14,	Report,	4,	1891.
"	5,	"	15–20,	"	5,	1892.
"	6,	"	21–26,	"	6,	1893.
"	7,	"	27–30,	"	7,	1894.
"	8,	"	31–35,	"	8,	1895.
"	9,	"	36–42,	"	9,	1896.
"	10,	"	43–46,	"	10,	1897.
"	11,	"	47–51,	"	11,	1898.
"	12,	"	52–55	"	12,	1899.
"	13,	"	56–69,	"	13,	1899–1900.
"	14,	"	70–78,	"	14,	1900–1901.
"	15,	"	79–86,	"	15,	1901–1902.
"	16,	"	87–94,	"	16,	1902–1903.
"	17,	"	95–101,	"	17,	1903–1904.
"	18,	"	102–107,	"	18,	1904–1905.
"	19,	"	108–114,	"	19,	1905–1906.

* Vols. 1–3 in one cover. Beginning with volume 4, a title page and index for each volume is to be found at the end of the annual report for each year. The year covered by a volume formerly was the calendar year, but now it extends from July 1 to June 30. Each volume, beginning with volume 4, is paged separately. The Bulletins of a given year precede the Report, and the latter is paged in continuation of the last Bulletin belonging in the volume.

EXCHANGES.

Aboriculture, Connersville, Ind.
Agricultural Advertising, Pittsburg, Pa.
Agricultural Epitomist, Spencer, Ind.
Agricultural Gazette of New South Wales, Australia.
Agricultural Ledger, Calcutta, India.
American Cultivator, Boston, Mass.
American Fancier, Johnstown, N. Y.
American Farm World, Augusta, Maine.
American Fertilizer, Philadelphia, Pa.
American Hay, Flour and Feed Journal, New York.
American Horse Breeder, Boston, New York and Chicago.
American Fruit and Nut Journal, Petersburg, Va.
American Philosophical Society, Proceedings of the Society.
American Poultry Advocate, Syracuse, N. Y.
American Poultry Journal, Chicago, Ill.
American Sheep Breeder and Wool Grower, Chicago, Ill.
American Stock Farm, The, Winona, Minn.
American Stock Keeper, Boston, Mass.
American Sugar Industry and Beet Sugar Gazette, Chicago, Ill.
Breeder's Gazette, Chicago, Ill.
Boletim de Museu Goeldi, Para, Brazil.
Boletin Oficial de la Secretaria de Agricultura, Havana, Cuba.
Bulletins of the Botanical Department of Jamaica, and Reports of Public Gardens and Plantations.
Bulletins of the New York State Museum.
California Cultivator, Los Angeles, Cal.
Chicago Daily Drover's Journal, Chicago, Ill.
Colman's Rural World, St. Louis, Mo.

Connecticut Farmer, New Haven, Conn.
Cotton Seed, The, Atlanta, Ga.
Elgin Dairy Report, Elgin, Ill.
Evening Tribune, Providence, R. I.
Farm and Fireside, Springfield, Ohio.
Farm and Live Stock Journal, Detroit, Mich.
Farm Journal, Philadelphia, Pa.
Farm Life, Chicago, Ill.
Farm Poultry, Boston, Mass.
Farm, Stock and Home, Minneapolis, Minn.
Farmers' Advocate, London, Ontario.
Farmers' Guide, Huntington, Ind.
Farmers' Review, The, Chicago, Ill.
Feather, The, Washington, D. C.
Feathered World, The London, England.
Flour and Feed, Waukegan, Ill.
Fruit Grower, The, St. Joseph, Mo.
Geflügel-Züchter, Hamburg, Wis.
Hoard's Dairyman, Fort Atkinson, Wis.
Holstein-Fresian Register, Brattleboro, Vt.
Homestead, The, Des Moines, Iowa.
Hospodárské Listy, Chicago, Ill.
Indiana Farmer, Indianapolis, Ind.
Journal Royal Horticultural Society, London, England.
Kansas Farmer, Topeka, Kansas.
Kimball's Dairy Farm, Waterloo, Iowa.
Maryland Agricultural Quarterly, College Park, Md.
Massachusetts Ploughman, Boston, Mass.
Metropolitan and Rural Home, The, New York City.
Michigan Farmer, The, Detroit, Mich.
Miscellaneous Publications, Department of Agriculture and Mines, Natal, Africa.
Modern Farmer and Busy Bee, The, St. Joseph, Mo.
Missouri Agricultural College Farmer, Columbia, Mo.

National Stockman and Farmer, Pittsburg, Pa.
Nebraska Farmer, Omaha, Neb.
New England Farmer, Brattleboro, Vt.
New England Homestead, Springfield, Mass.
New Farm, Preston, Md.
New Zealand Dairyman, The, Wellington, N. Z.
New Hampshire Farmer and Weekly Union, Manchester, N. H.
Northwest Horticulturist, Tacoma, and Seattle, Wash.
Nut Grower, The, Poulan, Ga.
Ohio Farmer, Cleveland, Ohio.
Oregon Agriculturist, Portland, Oregon.
Orff's Farm and Poultry Review, St..Louis, Mo.
Pacific Dairy Review, San Francisco, Cal.
Poultry, Peotone, Ill.
Poultry Gazette, Kansas City, Kans.
Poultry Herald, St. Paul, Minn.
Poultry Husbandry, Waterville, N. Y.
Poultry Keeper, Quincy, Ills.
Poultry Standard, Stamford, Conn.
Poultry Success, Des Moines, Iowa.
Poultry Topics, Lincoln, Neb.
Practical Farmer, The, Philadelphia, Pa.
Practical Fruit Grower, Springfield, Mo.
Prairie Farmer, The, Chicago, Ill.
Publications of the Department of Agriculture, Ontario, Canada.
Publications of the Florida Department of Agriculture.
Publications of the Department of Agriculture, Mysore State, India.
Publications of the Imperial Agricultural Experiment Station, Nishigahara, Tokyo, Japan.
Publications of the Maine State Board of Agriculture.
Publications of the Massachusetts State Board of Agriculture.
Publications of the Department of Agriculture, New Zealand.
Publications of the North Carolina State Board of Agriculture.
Publications of the Ohio State Board of Agriculture.

Publications of the Department of Agriculture, University College, North Wales.
Publications of the Pennsylvania Department of Agriculture.
Publications of the Rhode Island State Board of Agriculture.
Publications of the Department of Agriculture, Victoria.
Publications of the Virginia Department of Agriculture.
Publications of the Department of Agriculture of Western Australia.
Queensland Agricultural Journal, Australia.
Reliable Poultry Journal, Quincy, Ill.
Republic, The, St. Louis, Mo.
Rock Products, Louisville, Ky.
Rural New-Yorker, New York City.
Rural World, London, England.
Skandinavisk Farmer Journal, Minneapolis, Minn.
Southern Fancier, Atlanta, Ga.
Southern Farm Magazine, Baltimore, Md.
Southern Planter, Richmond, Va.
Successful Farming, Des Moines, Iowa.
Successful Poultry Journal, Chicago, Ill.
Sugar Beet, The, Philadelphia, Pa.
Sec. da Agr. Estado de Sao Paulo, Boletim da Agriculture.
Texas Farmer, Dallas, Tex.
Town and Country Journal, San Francisco, Cal.
Up-to-Date Farming and Gardening, Indianapolis, Ind.
Wallace's Farmer, Des Moines, Iowa.
Western Fruit Grower, St. Joseph, Mo.
W. Weddel & Co's. Colonial Dairy Produce Report, London, Eng.
West Virginia Farm Review, Charleston, W. Va.
Wilson Bulletins, Wilson Ornithological Club, Oberlin, Ohio.
Wisconsin Agriculturist, Racine, Wis.
Year Book, and current publications of the Deutschen Landwirtschafts-Gesellschaft.

BULLETINS

AND

ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDING JUNE 30,

1906.

PROVIDENCE:
E. L. FREEMAN COMPANY, STATE PRINTERS,
1907.

INDEX

OF THE

BULLETINS AND ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDING JUNE 30, 1906.

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Note.—For pp. 1–12 see Bul. 108; for pp. 13–44 see Bul. 109; for pp. 45–60 see Bul. 110; for pp. 61–74 see Bul. 111; for pp. 75–96 see Bul. 112; for pp. 97–114 see Bul. 113; for pp. 115–137 see Bul. 114.

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Rhode Island.

Report

Agricultural Experiment Station,

Year Ended June 30,

1907

STATE OF RHODE ISLAND

HOPE

PART II
TWENTIETH ANNUAL REPORT.

FORMAL REPORT OF
E BOARD OF MANAGERS
IS PART I.

COLLEGE CATALOGUE
IS PART III.

Kingston,

R. I.

State of Rhode Island and Providence Plantations.

TWENTIETH ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, 1906-1907.

PART II.

OF THE

TWENTIETH ANNUAL REPORT

OF THE

CORPORATION, BOARD OF MANAGERS

OF THE

Rhode Island College of Agriculture and Mechanic Arts,

MADE TO THE

GENERAL ASSEMBLY AT ITS JANUARY SESSION, 1908.

[PARTS I. AND III. OF THIS REPORT — REPORT OF PRESIDENT AND BOARD OF MANAGERS AND COLLEGE CATALOGUE — ARE PRINTED UNDER SEPARATE COVERS.]

PROVIDENCE, R. I.
E. L. FREEMAN COMPANY, PRINTERS TO THE STATE.
1908.

The Station.

BOARD OF MANAGERS

OF THE

RHODE ISLAND

College of Agriculture and Mechanic Arts.

STATION COUNCIL.

Howard Edwards, M. A., LL. D............... President of the College. *Ex-officio* Member.
H. J. Wheeler, Ph. D..................Director, Chemistry and Agronomy.
Fred W. Card, M. Sc...................................Horticulture.
Leon J. Cole,* Ph. D.....................Animal Breeding and Pathology.
Burt L. Hartwell,† Ph. D..........................Associate, Chemistry.
George E. Adams, B. Sc............................Associate, Agronomy.
W. F. Kirkpatrick,‡ B. Agr., B. E.......Asst., An'l Breeding and Pathology.
J. Willard Bolté, B. Sc.......................Assistant, Animal Feeding.
P. H. Wessels, B. Sc.............................Assistant, Chemistry.
F. R. Pember, B. Sc......................Assistant, Physiological Botany.
S. C. Damon, B. Sc...............................Assistant, Agronomy.

OTHER MEMBERS OF THE STATION STAFF.

J. Frank Morgan, M. A.............................Assistant, Chemistry.
H. S. Hammond, B. S. A............................Assistant, Chemistry.
L. F. Whipple.....................................Assistant, Chemistry.
Nathaniel Helme...................................Meteorology.
Beulah A. Hoitt..........................Stenographer and Accountant.
E. Elizabeth Meears.......................Stenographer and Librarian.

The publications of the Station will be mailed free, upon request, to all residents of Rhode Island to whom they are of interest. Suggestions as to how the Station can aid the State are gladly received. Visitors are always welcome. Railway station, telegraph, express, and post-office—Kingston, Rhode Island. Long distance telephone, Narragansett Pier Exchange.

*Expert in the Bureau of Animal Industry, U. S. Department of Agriculture. Engaged in co-operative work between the Bureau and Station.

†In charge of experiments in Plant Physiology.

‡Agent, Bureau of Animal Industry, U. S. Department of Agriculture Engaged in co-operative work between the Bureau and Station.

LETTER OF TRANSMITTAL.

To His Excellency, James H. Higgins, Governor, and the Honorable the General Assembly of the State of Rhode Island, at its January Session, 1908.

KINGSTON, R. I., January 1, 1908.

I have the pleasure to present herewith, in compliance with the statute of the State and the Congressional acts of March 2, 1887, and March 16, 1906, the Report of the Director of the Rhode Island Agricultural Experiment Station for the year ended June 30, 1907.

Respectfully submitted,

For the Board of Managers,

CHARLES DEAN KIMBALL,

President.

AGRICULTURAL EXPERIMENT STATION

OF THE

RHODE ISLAND COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

KINGSTON, R. I., June 30, 1907.

HON. CHARLES DEAN KIMBALL,

President, Board of Managers.

SIR:—I have the honor to transmit herewith the Twentieth Annual Report of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1907.

Respectfully yours,

HOWARD EDWARDS,

President.

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DIRECTOR'S REPORT.

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REPORT OF THE DIRECTOR.

H. J. WHEELER.

To Howard Edwards, President.

Sir:—It gives me pleasure to render a report on the work of the Experiment Station for the past year. In doing so the material is presented topically with the hope that it may thus be made more accessible to the average reader.

Division of Horticulture.

The work of the Division of Horticulture has been practically a continuation of that outlined in previous reports. Its main features have been:

(1) Trials of grasses and of various combinations of manures to ascertain their adaptability to the production and maintenance of turf adapted to polo grounds, golf links, and lawns; (2) Rotation of garden crops to test the relative cost and efficiency of stable manure as compared with chemical manures and catch crops; (3) Clover selection and breeding in the attempt to secure an improved strain of common red clover; (4) Interpollination experiments with blackberries to ascertain if it is better to plant two kinds together than each separately; (5) Strawberry breeding in order to secure, if possible, extra late varieties; (6) Selection and breeding of raspberries in the attempt to secure an extra early berry of good marketable quality; (7) Selection of sweet corn to improve the bearing quality and number of ears per stalk.

A detailed discussion of such part of the work of this division as is sufficiently advanced for publication at this time may be found in the later pages of this report in the "Report of the Division of Horticulture."

Owing to the resignation of Professor Card, which went into effect on June 30, 1907, arrangements have been perfected with Professor G. E. Adams, formerly assistant in horticulture and later associate in agronomy in the Station, to assume charge of the work of the division for the coming year.

Division of Chemistry.

Owing to the many other duties of the Director, the detailed supervision of the work of this division has been delegated to my associate, Doctor Hartwell. The work has covered the chemical analysis involved in the general lines of investigation carried on by the Station, also that connected with the inspection of commercial feeding-stuffs and of commercial fertilizers.

The division has been continuing the investigations for the purpose of studying the function of sodium salts in connection with plant growth, by means of the growth of plants in solutions.

Experiments have been in progress to ascertain the merits of the paraffined wire basket and of the Wagner pot in ascertaining the deficiencies and faults of soils, and one bulletin on this subject has been published during the year. In addition there have been published two bulletins on commercial fertilizers and one on commercial feeding-stuffs.

A new study has been made of the cause of the efficiency of lime as exhibited in connection with certain of the field experiments.

In order to throw light upon the probable efficiency of powdered feldspar as a source of potash for agricultural plants, this material has been tested, during the winter and spring, by way of pot culture in ordinary soil. The results thus far secured do not, however, warrant the belief that this material, without further treatment, can

economically replace the commercial potash salts for general agricultural purposes.

The miscellaneous analyses of the year, and other matter relating to the work of this division, may be found embodied in this report under "Report of the Chemical Division."

DIVISION OF ANIMAL BREEDING AND PATHOLOGY.

Early in the year Doctor Curtice, who has been at the head of the Division of Animal Husbandry, received an offer of a temporary position with the Bureau of Animal Industry of the U. S. Department of Agriculture, and, in order to accept, asked for a temporary leave of absence, which was granted. He also tendered his resignation, to take effect on June 30, 1907, but later the date was changed, at his request, to April 1. Doctor Curtice left in August to fill this temporary appointment, and returned on December 1 to prepare for publication a report on his previous work. He was thus engaged, in addition to certain duties in the College, until April 1, 1907.

On September 1, 1906, Dr. Leon J. Cole was appointed to fill the position of Chief of the Division of Animal Breeding and Pathology, which had been created in the meantime. In addition to possessing a practical knowledge of agricultural matters, he was for two years a student at the Michigan Agricultural College, also for four years at the University of Michigan, and for a like period at Harvard University. He has taken hold of the work in a determined and systematic manner, and will make a study of certain problems connected with animal breeding and with the diseases of fowl, with special reference to the so-called "blackhead" disease of turkeys. This latter line of work, as well as that of breeding turkeys, was begun by Doctor Curtice.

It is but fair to the public to say that this is a most difficult and complex field of labor, and it must not be expected that great and far-reaching results will be secured immediately, for it may take many years to fully solve any one of the problems under consid-

eration, yet it is hoped that much of practical value will be ascertained at an early date. The very fact of the difficult nature of the work furnishes the strongest argument why it should be taken up at once and prosecuted vigorously.

It is hoped that the public will be sufficiently patient to allow this investigation to go on for a number of years, if necessary. In this connection one should bear in mind that the long-continued study of Texas fever in cattle and of malaria and yellow fever in the human family has finally shown that the tick and mosquito convey the diseases, and that in consequence of this discovery the practical elimination of these scourges has been made possible.

A general statement concerning the work of the year may be found in the "Report of the Division of Animal Breeding and Pathology."

DIVISION OF ANIMAL FEEDING.

At the beginning of the year arrangements were made for undertaking experimental work in poultry feeding. This work was placed temporarily in charge of Mr. J. W. Bolté, a graduate of the Michigan Agricultural College, who had been connected for one year with the Agricultural Experiment Station of the Utah Agricultural College. Mr. Bolté also acted as instructor in animal husbandry in the College. The work undertaken has been as follows:

(1) The feeding of young chicks to study the influence of different nitrogenous feeding-stuffs.

(2) A feeding and fattening experiment with cockerels.

(3) A feeding experiment with capons.

(4) A fattening experiment with turkeys.

(5) A feeding experiment with hens to study the influence of feed and methods of feeding upon egg production.

It was hoped that a report of all of the experiments excepting the first and last could be embodied in this report, but owing to delay in their preparation for publication the results will have to be issued in a later publication.

PUBLICATIONS.

The following is a list of the bulletins which have been published during the fiscal year:

No. 115, Commercial Fertilizers, July 1906, pp. 1–16.

No. 116, Corn Selection, October, 1906, pp. 16–36.

No. 117, Analyses of Commercial Fertilizers, November, 1906, pp. 37–52.

No. 118, Continued Test of Nine Different Phosphates with Different Plants, March, 1907, pp. 53–86.

No. 119, Commercial Feeding-Stuffs, April, 1907, pp. 87-108.

No. 120, Soil Tests in Paraffined Wire Baskets Compared with Tests on Farms, May, 1907, pp. 109–138.

No. 121, A Study of Rhode Island Soil Requirements by Means of Field Tests, June, 1907, pp. 139–176.

No. 122, Analyses of Commercial Fertilizers, June, 1907, pp. 177–188.

IMPROVEMENTS.

During the year additional turkey yards have been covered with netting so as to make it possible to conduct breeding work with wild turkeys. Many of the turkey pens have also been subdivided so as to facilitate the keeping of the pedigree records of all of the birds reared.

A rat-proof seed room has also been provided in the barn on the plain. Two additional buildings for the poultry plant have been provided by moving to the poultry grounds the old apiary house and an old house which had been left behind on the plain when the poultry plant was moved to its present location in 1901.

The telephone system became so poor early in the year that it was practically useless, and a new one was installed which has thus far given practically perfect satisfaction. In addition an intercommunicating telephone system was installed in the Station building, by which persons in any room can communicate with those in any other without calling the central office. This system has thus far worked most satisfactorily, and has not only proved to be a great

convenience to everyone in the building but also a great economizer of time, especially for the Director. This is particularly the case on account of the fact that the Director has no private office and is subject to the disturbance incident to every item of business transacted in the public office.

During the year a calculating machine has been added to the Station equipment. This machine facilitates especially multiplication and division. This can be best realized when it is stated that in division a turn of the crank accomplishes a multiplication and subtraction; hence four figures in the quotient are obtained by four revolutions. The occurrence of an error in the work is announced by the ringing of a bell.

A water pipe has been laid from the College pumping station to the barn on the plain. A hydrant has also been provided near the barn, in order to furnish fire protection as well as water for various purposes.

In consequence of the completion of the greenhouse, facilities are now afforded for conducting experiments in floriculture and in vegetable gardening under glass, also for winter work in water culture in connection with the study of the functions and relations of the various elements connected with plant growth.

NEEDS.

The old glass pot-culture house is in bad condition, and it should now be repaired or moved to a location near the new greenhouse so that it can be heated and may thus be utilized both in summer and winter for pot vegetation experiments as well as for work in water culture. If this new provision were made, space would be relieved in the new greenhouse which would be available for more extended experiments with vegetables and flowering plants.

Attention has been called previously to the fact that a private office should be provided for the Director, where, in the preparation of manuscript and in attention to other official duties, there will be

reasonable freedom from unnecessary interruption incident to being obliged to work in the general office where all of the business of the Station is transacted.

Attention has already been called, in a previous report, to the need of a dry, fire-proof, and commodious vault for the storage of the records of experiments, provision for which should be made in the very near future.

It is important that the Station should also have a dry, fire-proof, and suitable storage room for samples of crops and of other materials which are now kept in the attic, subject to danger from fire.

The interior of the Station building is also in need of general repairs.

Attention should be called to the fact that it will be out of the question to take up a study of the manurial treatment of orchards, and that extended efforts to produce a hardy peach will also be impossible, unless more land is provided for the permanent use of the Station.

CHANGES IN THE STATION STAFF.

On July 1, J. W. Bolté, B. Sc., a graduate of the Michigan Agricultural College, who had been for one year employed at the Agricultural Experiment Station of the Utah Agricultural College, took up his duties as assistant in the Division of Animal Feeding.

Doctor Cooper Curtice was granted a leave of absence from August to December, 1906, for the purpose of accepting a position with the Bureau of Animal Industry, U. S. Department of Agriculture. He also tendered his resignation, to go into effect on June 30, 1907, but this date was changed later, at his request, to March 31, 1907. During the years that Doctor Curtice has been connected with the Station he has devoted himself most assiduously to the details of the development of the experimental poultry plant. In addition he has accomplished much in the study of the so-called "blackhead" disease of turkeys, an account of which will be given in subsequent publications of the Station. He has continued his earlier work on incuba-

tion and brooding, and it is hoped to be able to present this material to the public at some time in the future.

Owing to resignation to accept a position in California, F. L. Yeaw terminated his detail at this Station on August 1, 1906.

On September 1, L. J. Cole, Ph. D., of Harvard University, was appointed chief of the new Division of Animal Breeding and Pathology. He appears to be especially adapted to the work in hand, as shown by the elaboration of a most systematic scheme for records, and by systematizing generally the experimental work.

On January 31, H. L. Barnes, assistant horticulturist, tendered his resignation; and on March 15, E. A. Malette, of the Mt. Hermon School, was appointed assistant in floriculture.

One of the vacancies in the Chemical Division was filled, on August 20, by the appointment of H. S. Hammond, B. S. A., a graduate of the Wye Agricultural School, England, and of the Ontario Agricultural College, Canada. In addition to his other experience Mr. Hammond had been employed for some time in the government laboratory at Jamaica.

On December 1, F. R. Pember, B. Sc., a graduate of the University of Vermont, who was in the employ of the Bureau of Soils, and had been detailed to the Station to assist in coöperative pot and water-culture work, accepted a position at this Station as assistant to Doctor Hartwell, in his work in plant physiology.

A second vacancy in the Chemical Division was filled, on March 15, by the appointment of L. F. Whipple, who had been a special student in chemistry at Brown University and at the University of Maine.

In anticipation of the promotion of G. E. Adams to the position of Professor in the College and as temporary horticulturist to the Station, S. C. Damon, B. Sc., a graduate of the Massachusetts Agricultural College, was appointed assistant in agronomy in order to relieve Mr. Adams of certain of the details of the work in agronomy.

Professor F. W. Card, who has been connected with the College and Station for many years, and who has had charge of the Division

of Horticulture, tendered his resignation, to take effect on June 30, 1907.

COÖPERATIVE WORK.

The coöperative work between the Bureau of Animal Industry, U. S. Department of Agriculture, and this Station was transferred, in the spring of 1907, from the Division of Animal Husbandry of the Bureau to the Division of Pathology.

The coöperation between the Bureau of Soils and the Station was discontinued during the year, though the Bureau is kindly loaning the Station the outfit for work with paraffined wire baskets, in order that further trials of them may be made the present season.

The Bureau of Plant Industry, U. S. Department of Agriculture, is supplying the Station with seed of early varieties of Indian corn and of perennial clover, for trial at Kingston.

ACKNOWLEDGMENTS.

It is a source of much regret to lose the services of Professors Card and Curtice, both of whom have been most agreeable and honorable in all of their personal and official relation.

Professor Curtice has been tireless in his devotion to the details involved in developing the present Station poultry plant, which is a monument to his industry and perseverance.

Professor Card also leaves a monument in the shape of the new greenhouse, and has always been especially punctual in the presentation of matter for publication, and with Professor Curtice has always given the Director loyal support in everything which was for the best interest of the Station. Both of these gentlemen leave with the utmost respect and esteem of the entire Station staff, and with my personal gratitude and best wishes.

The Station has been especially fortunate in retaining the services of Doctor Hartwell and Professor Adams, both of whom have

attended to their varied and increasing duties in a most satisfactory way.

It is a particular pleasure to speak of the satisfactory manner in which Doctor Cole has taken hold of the work in his division.

My thanks are especially due Doctor Hartwell for assistance in connection with the reading of proof-sheets, and to Miss Hoitt for her most efficient service as stenographer and accountant in connection with the administrative work of the Station.

My thanks are due to the other employees of the Station, who, without exception, have been most faithful and attentive to their several duties. In fact, the Station is especially fortunate at this time in its personnel of assistants in the several divisions.

Respectfully submitted,

H. J. WHEELER,

Director.

HORTICULTURAL DIVISION.

HORTICULTURAL DIVISION.

FRED W. CARD.

A report of the regular work of the Horticultural Division during the year 1906–7 appears in the succeeding pages, followed by an account of some minor and long-time experiments which have been under way during the connection of the writer with the Station.

Apple-Maggot.—In the season of 1905 no pupæ were obtained for experimental work with the apple-maggot.

Early Harvest apples in the old orchard were riddled with maggots, notwithstanding the fact that hogs had the run of the orchard the previous year and were there again in 1905. Maggots were also quite numerous in the early apples in the variety orchard.

In October three frames each 3x4 feet in size, covered by a wire screen, were placed in the garden. One hundred fifteen apples were placed in each frame; these were a rather small, sweet variety from a wild tree growing on the College farm. They were taken from the ground and distributed as evenly as possible in these frames. In frames Nos. 1 and 2 the apples were left upon the surface. In frame No. 3 the soil was removed to a depth of six inches, the apples were then spread in the bottom and the soil replaced over them.

In 1906 the soil in frames Nos. 1 and 3 was left undisturbed. In frame No. 2 the soil was frequently hoed over during the season, the object being to determine, if possible, whether disturbing the ground, as done in a well-tilled orchard, has any influence upon the number of flies which emerge. Rather strangely and unfortunately, though in line with the experience of 1904, only one fly was observed during the entire season, and this was in the frame in which the soil had been kept tilled. We are at a loss to account for this failure to ob-

serve the emergence of flies in 1904 and 1906, as in previous experiments, which are recorded in the annual report for 1904, no difficulty was experienced in obtaining flies from buried pupæ or from frames underneath trees in the orchard. Whether some parasitic enemy was at work, or whether the full exposure to sunlight which these frames had in the open garden had some influence, or whether there was some other reason, it is impossible to say.

Bush-fruits.—A large number of crosses between different varieties of raspberries and blackberries have been made during the past years. Some six hundred plants have been given places in the field, where they have been under observation for their individual qualities. Very few of these have shown any real promise. The following general notes may be of interest as showing something of the tendencies resulting from some of the variety crosses:

Loudon X Cuthbert.—Color good, but fruit small.

Early King X Cuthbert.—A promising cross; not many plants of this were obtained, but the fruit seemed much like Cuthbert in size and shape, and brighter in color. Two plants of this parentage have been chosen for propagation; one in particular appears to be a great improvement on the Cuthbert in color (Fig. 1).

Miller X Cuthbert.—Productive, fruit of small to medium size, dark, and unattractive in color as a rule, much of it crumbly.

Cuthbert X Coutant.—Fruit nearly all bright colored (very much better than that of the Cuthbert in this respect), variable in size, some fairly good.

Cuthbert X Shaffer.—Plants apparently all propagating naturally by suckers, but show strong upright growth characteristic of the Shaffer. The spines appear stronger than in most red varieties. Anthracnose has been noticeable on some of the canes. The fruit has appeared to be but little darker than Cuthbert, with drupelets larger in some cases.

Coutant X Cuthbert.—Fruit apparently of bright color, mostly round but not large.

Miller X Shaffer.—Hardier than most of the seedlings obtained.

FIG. 1.—TWO RASPBERRY SEEDLINGS.

Fruit all dark and round with large drupelets, size fairly good in some cases.

Shaffer X Miller.—Hardy and productive as a rule. A number of these plants have shown a pronounced black-cap habit and appeared as though they would propagate from tips. Some of the fruit has shown marked black-cap flavor. Other plants show more of the characteristics of red varieties, both in fruit and plant. On a few of these latter the fruit is rather lighter than that of the Shaffer and of good size, but in general the fruit is small to medium, dark, round, and of good flavor. One promising plant, with fruit apparently much lighter in color than the Shaffer, has been chosen for propagation.

Worthy X Cuthbert.—Growth vigorous. Fruit mostly rather small and dark.

Shaffer X Golden Queen.—Only three plants of this cross have been grown. One showed Shaffer fruit with Golden Queen plant and yellowish foliage, one showed Shaffer or black-cap habit, the other Cuthbert habit. Records of the fruit of only one have been made. The fruit in this case was small and dark, but not so dull as that of the Shaffer, having something of a wine color, with large drupelets, and resembling a black-cap more than the Shaffer does.

Columbian X Miller.—Plants hardy and productive. Fruit of fair size, rich, and possessing much of the black-cap flavor. Plants apparently healthier than those of Shaffer parentage. Fruit of good size for a black-cap, but small for a red. One plant of this cross is really promising. Its fruit is of unusually good quality, very rich and pleasant, combining much of the flavor of the black-cap with that of the red varieties, and averaging larger in size than black-caps.

Cuthbert X Miller.—Over two hundred plants of this cross have been in fruit; they are fairly hardy, but it is not the right cross to improve the color and quality of Cuthbert. The fruit in nearly all cases is small and dark, though on an occasional plant it resembles that of the Cuthbert. A single plant of this, which appears to bear brighter fruit than the Cuthbert, has been chosen for propagation.

Many of the plants obtained from the blackberry crosses have died, and none has shown any real value.

Clover Selection.—Additional sowings of Medium and Mammoth clover from the seed used in the experiment begun in 1903* were made in the spring of 1904. This seed was obtained from eight different seedsmen, one lot from each being purchased as Medium and one as Mammoth clover. In several cases that labelled Mammoth proved to be Medium or badly mixed.

In 1905 over thirty plants were described in detail, and seed was saved from them for planting. Detailed descriptions of these plants are uncalled for, but it may be said that they varied in many ways, among which were the following:

1. Height of plant, which ranged from two to nearly four feet.
2. Number and proportionate weight of stems.
3. Size and color of stems.
4. Season of bloom.
5. Size of bloom.
6. Number, color, size, and shape of leaves.
7. Character of leaf markings.

The seed saved from these plants was sown in the chaff, June 26, 1906, ten hills of each number being planted. After the plants were established, they were thinned to a single one in each hill. Brief notes have been made upon the character of these different lots, but careful observations with a view to future selection must await the blooming period in 1907. Some of them promise to afford very desirable types. Unfortunately, the greater number of these plants did not survive the winter. In many cases every plant of the ten saved from a given parentage died. In only one case did as many as nine live. In order to bring them together and utilize space to better advantage, those which lived were moved in the spring of 1907.

Part of the loss was due to a depression in the ground through which these rows ran, where water evidently stood for a time during

* See annual report for 1904, p. 202.

the winter. On ground not subject to this influence the plants seemed to vary greatly in hardiness.

As a problem for student investigation, Mr. A. E. Wilkinson, a senior in the College, was given a lot of Medium red clover seed from which to separate purple and yellow seeds for comparison. One hundred hills were planted with seeds of each type, these being thinned to one plant in a hill after they were well established. His notes show that the purple seeds germinated a trifle better than the yellow seeds. Detailed notes regarding the appearance of the individual plants in the different lots are not available, but twelve plants from each lot were selected for analysis October 12, 1905. These were cut just above the ground, the roots not being included in the analyses. The percentages of nitrogen found in these plants were as follows:

NITROGEN IN DRY MATTER.

Grown from Purple Seeds. Plant No.	Percentage of Nitrogen.	Grown from Yellow Seeds. Plant No.	Percentage of Nitrogen.
1	3.76	13	3.29
2	2.86	14	3.29
3	4.04	15	3.39
4	3.59	16	3.34
5	3.56	17	4.62
6	3.42	18	3.59
7	3.68	19	3.79
8	3.55	20	2.95
9	3.41	21	3.39
10	3.41	22	4.06
11	3.30	23	3.66
12	3.27	24	3.56
Average	3.48	Average	3.58

These figures show no material difference in average nitrogen content between the plant's grown from purple seeds and those grown from yellow seeds. It will be seen, however, that there are striking differences in the nitrogen content of different individual plants, varying from 2.86 in the lowest to 4.62 in the highest, an increase of

over 60 per cent. Whether this difference would be perpetuated in the offspring of these different plants can only be conjectured, but it indicates that there may be a possibility of materially influencing the protein content of clover hay through the line of seed selection. Repeated analyses in conjunction with careful records concerning the characteristics of individual plants and their offspring are needed.

Corn Selection.—In 1906 the "selection" corn was planted on land which was in strawberries in 1905. After fruiting, the strawberries were turned under and a cover crop of Mammoth clover sown. This had grown so high that it was mown and spread before plowing the ground for corn in 1906, which was done May 24, the corn being planted the following day.

The fertilizer used was as follows:

	Rate per acre.
Nitrate of soda	100 lbs.
Dried blood	200 "
Acid phosphate	500 "
Muriate of potash	200 "

Six rows from seed produced by plants bearing thirteen ears in 1905, and thirteen rows from plants bearing eleven ears in 1905, were planted. The rows were three feet apart, with hills two feet apart in the row. Two kernels were placed in each hill, the plants being thinned to one in each hill after being established. In harvesting, the six rows grown from thirteen-ear seed and four of the rows grown from eleven-ear seed were carefully cut and shocked for husking, each plant being tied together with strong cord before being cut. The remaining nine rows were nearer to plots containing variety tests with field corn, and were not so carefully handled, but a count showing the number of ears per plant was made as the plants were growing in the field. The following table shows the result of this count:

Nine Rows from Eleven-Ear Seed.

		Per cent.
Plants with one ear	7	.9
Plants with two ears	51	6.8
Plants with three ears	106	14.2
Plants with four ears	215	28.9
Plants with five ears	209	28.1
Plants with six ears	112	15.0
Plants with seven ears	34	4.6
Plants with eight ears	9	1.2
Plants with nine ears	2	.3
	745	100.0

Records of the product from the following rows were made at husking time, and are presented below:

Six Rows from Thirteen-Ear Seed.

No. of ears per plant.	No. of plants.	Percentage relation.	No. of good ears.	No. of poor ears.	Average number of good ears per plant.	Total weight of ears, (lbs.)	Average weight per ear, (oz.)	Average weight per plant, (oz.)
1	11	2.0	10	1	1.0			
2	18	3.4	27	9	1.5			
3	65	12.1	148	47	2.3	504.0	4.9	20.0
4	156	29.0	460	164	2.9			
5	154	28.6	519	251	3.4			
6	77	14.3	302	160	3.9	123.8	4.3	25.7
7	39	7.3	152	121	3.9	63.5	3.7	26.1
8	12	2.2	49	47	4.1	29.8	5.0	39.7
9	4	.7	16	20	4.0	5.5	2.4	22.0
10	2	.4	10	10	5.0	3.0	2.4	24.0
Total	538	100.0	1,693	830	...	729.6	Av. 4.6	21.3

Four Rows of Eleven-Ear Seed.

No. of ears per plant.	No. of plants.	Percentage relation.	No. of good ears.	No. of poor ears.	Average number of good ears per plant.	Total weight of ears, (lbs.)	Average weight per ear, (oz.)	Average weight per plant. (oz.)
1....	17	4.8	14	3	.8			
2....	100	28.5	148	52	1.5			
3....	76	21.7	144	84	1.9	276.3	4.6	14.2
4....	68	19.4	187	85	2.8			
5....	50	14.2	157	93	3.1			
6....	27	7.7	105	57	3.9	41.0	4.0	24.3
7....	10	2.8	52	18	5.2	20.0	4.6	32.0
8....	3	.9	15	9	5.0	6.5	4.3	34.7
Total..	351	100.0	822	401	...	343.8	Av. 4.5	15.6

From the above tables the following facts are deduced.

Corn Grown from Thirteen-Ear Seed.

Average weight of ears per plant	21.3	ounces.
Average weight of ear	4.6	"
Average number of ears per plant	4.6	
Average number of good ears per plant	3.1	

Corn Grown from Eleven-Ear Seed.

Average weight of ears per plant	15.6	ounces.
Average weight per ear	4.5	"
Average number of ears per plant	3.5	
Average number of good ears per plant	2.3	

Taking all the plants together, grown both from the eleven and the thirteen-ear seed, the following averages are obtained:

Average weight of ears per plant	19.3	ounces.
Average weight per ear	4.6	"
Average number of ears per plant	4.2	
Average number of good ears per plant	2.8	

The following averages are available from the whole nineteen rows, being made from the field count of the nine rows not carefully husked and the husking count of the remaining ten rows:

	No.	Per cent.
Plants with one ear	35	2.1
Plants with two ears	169	10.3
Plants with three ears	247	15.1
Plants with four ears	439	26.9
Plants with five ears	413	25.3
Plants with six ears	216	13.2
Plants with seven ears	83	5.1
Plant with eight ears	24	1.5
Plants with nine ears	6	.4
Plant with ten ears	2	.1
Total	634	100.0

No single plant in 1906 bore as many ears as in 1905, the highest number being thirteen in 1905 and only ten in 1906, but the average number per plant increased, as will be shown by the following comparison:

Comparison of Crop of 1905 *with Crop of* 1906.

	1905.	1906. All seed.	1906. Thirteen-ear seed.
Average weight of ears per plant	15.52 oz.	19.3 oz.	21.3 oz.
Average weight of ears	4.00 oz.	4.6 oz.	4.6 oz.
Average number of ears per plant	3.9	4.2	4.6
Average number of good ears per plant	2.8	2.8	3.1

In 1905, 50 per cent. of the plants grown bore less than four ears. In 1906 only 27.5 per cent. bore less than four ears. The results, therefore, show a continued increase in the number of ears produced per plant.

The experiment is being continued in 1907. Corn of this same variety, Potter's Excelsior, obtained from a regular seedsman, is this

year being grown by the side of this which has been so long under selection, to determine what progress has been made.

Frost Resistant Beans.—The breeding of beans to determine whether it is possible to increase their frost resisting power was continued in 1906, as in former years. Fifty beans of each of the numbers given below were planted in hot-beds on April 3:

Field No.	Record No.								
(1)	15–1	'99,	'00,	'01,	'02,	'03,	'04,	'05 K.	
(2)	3	'99,	B. F.,	'00,	'01,	H.,	'02,	'03,	'04, '05.
(3)	9–1	'99,	'00,	K. F.,	'01,	H.,	'02,	'03,	'04, '05.
(4)	24–1	'99,	'00,	G. F.,	'01,	H.,	'02,	'03,	'04, '05.
(5)	2	'99,	B. F.,	'00,	'01,	H.,	'02,	'03,	'04, '05.

Nos. 1 and 3, as designated above, are Keeney's Rustless, as indicated by the letter K. Nos. 2 and 5 are Henderson's Bountiful. No. 4 is Golden-Eyed Wax. The letters F and H indicate that in the years following the particular strain was planted in the field or in the hot-bed, respectively. These beans germinated promptly and made a vigorous growth. The amount of air given was gradually increased, then the sashes were removed during the day and finally left off altogether the night of April 26, in order to expose the plants to frost.

A thick, white frost was observed on the plain on the mornings of May 1 and May 5. All the numbers showed more or less injury, which may have been due as much to cold wind as to frost. The plants of No. 1 suffered least, perhaps owing to location, being partly protected by a partition on the west side. Two rows of No. 3 had a similar protection, but were injured more. No. 2 appeared to suffer more than the others, all the plants having a yellow appearance. No. 4 was also hurt considerably. The plants most injured were removed May 5, but a number of those left in Nos. 2, 3, and 4 showed some injury to the leaves. The numbers removed were as follows:

No. 1, 9 plants; No. 2, 19 plants; No. 3, 11 plants; No. 4, 15 plants; No. 5, 8 plants.

Another heavy frost occurred the morning of May 11. Nearly all

the plants were frosted, at least all new growth. None wholly escaped, except a very few close to the partition, and most of these were hurt. The larger leaves were killed on all plants in the center of the beds. The plants most injured were pulled May 19, leaving the best as follows:

No.	Number pulled.	Number left.
1	20	19
2	13	17
3	12	26
4	11	22
5	18	23

The strains which have been grown in the open ground from year to year were planted on the plain, April 27, 1906. These were placed in rows three feet apart, with the beans one foot apart in the row. Two hundred and one beans of each number were planted, the numbers being as follows:

Field No.	Record No.
(6)	3 '99, B. F., '00, '01, '02, '03, '04, '05.
(7)	9-1 '99, '00, K. F., '01, '02, '03, '04, '05.
(8)	24-1 '99, '00, G. F., '01, '02, '03, '04, '05.
(9)	2 '99, B. F., '00, '01, '02, '03, '04, '05.
(10)	15-1 '99, '00, '01, '02, K. F., '03, '04, '05.

The purpose in this series has been to plant the beans early in order to subject them to frost, if it occurs after they are up, and to unfavorable weather conditions in germination. Unfortunately, an assistant planted these beans so deeply, in 1906, that they came up irregularly, and many of them were but just appearing on June 1. The only test, therefore, which this season afforded was that of their ability to stand cold weather and come through so much soil.

The following numbers in each row were found growing, July 10, from the 201 beans of each which were planted:

No.	
6	156 plants.
7	77 plants.
8	40 plants.
9	167 plants.
10	119 plants.

In order to determine whether any progress has been made in increasing the hardiness of these beans, seed of the same varieties was obtained from a seedsman in 1907 and planted with them. The beans grown in frames last year were found to be in bad condition at planting time, apparently having been hurt by the weather before they were gathered. It was therefore necessary to use seed of 1905 for part of the planting in frames.

The number of beans planted, as divided between old and new seed, was as follows:

No.	1905 seed.	1906 seed.
1	30	20
2	30	20
3	..	50
4	35	15
5	10	20

Seeds Obtained from Seedsman.

Golden Eyed Wax, 50.
Bountiful, 50.
Keeney's Rustless, 50.

These were planted in a cold-frame, April 2. The weather was cold, and the beans germinated very slowly. After some of them were up they were gradually hardened and had been left exposed to the weather some time when the freeze occurred, which happened on the night of May 11. This was a very cold night, and ice of considerable thickness was seen on the morning of May 12. A thermometer at the greenhouse stood at 29°. Most of the plants were badly hurt. Their condition, as noted May 12, was as follows:

No.	Seed.	Plants up.	Plants unhurt.
1.	1905	16	3
1.	1906	1	1
2.	1905	22	1
2.	1906	6	0
3.	1906	1	0
4.	1905	4	0
4.	1906	0	0
5.	1905	10	0
5.	1906	6	3

Seed from Seedsman.

Golden Eyed Wax	15	1
Bountiful	34	5
Keeney's Rustless	30	10

Some of the plants grown from seedsmen's seed seemed to be more completely killed than those from selected seeds, but a larger percentage remained unhurt. The poor condition of the seed selected in 1906 may have been responsible, in part, for the loss, owing to decreased vitality, but that would not apply to the seed of 1905, which was in good condition.

On May 29 the plants grown were again counted, and the following numbers found alive:

No.	Source of seed.		Number alive.
1.	(Keeney's Rustless)	1905	3
1.	" "	1906	0
2.	(Bountiful)	1905	7
2.	"	1906	2
One of these was apparently not up when the frost came.			
3.	(Keeney's Rustless)	1906	0
4.	(Golden Eyed Wax)	1905	1
Apparently not up when frost came.			
4.	(Golden Eyed Wax)	1906	0
5.	(Bountiful)	1905	1
5.	"	1906	3

Seedsmen's Seed.

		Number alive.
Golden Eyed Wax (from seedsman)	....	2
Bountiful " "	....	8*
Keeney's Rustless " "	....	12†

The beans in the field selection were planted April 23. Two hundred beans of each of Nos. 6, 7, 8, 9, and 10, also of Golden Eyed Wax, Bountiful, and Keeney's Rustless were planted in plat No. 103. Fertilizer was applied at the following rate per acre:

100 lbs. nitrate of soda.
500 lbs. acid phosphate.
200 lbs. muriate of potash.

The beans were very slow in germinating, owing to the cold, backward spring. An occasional plant was just beginning to show on May 27. On June 4 it was possible to count the following numbers in sight; some of these were only just breaking through the ground, but none were counted unless at least the curved stem of the young plant was to be seen:

No.
6. (Bountiful) 8 plants.
7. (Keeney's Rustless) 11 plants.
8. (Golden Eyed Wax) 23 plants.
9. (Bountiful) 3 plants.
10. (Keeney's Rustless) 13 plants.
Bountiful, from seedsman, 3 plants.
Keeney's Rustless, from seedsman, 2 plants.
Golden Eyed Wax, from seedsman, 11 plants.

Those which were up far enough to show real leaves all looked very small and weak, the leaves themselves being small. It is doubtful if any real frost occurred after these plants were up, but they had a hard trial owing to the very cold weather which prevailed.

It will be seen by the above account that in the case of the field beans a somewhat larger number of those grown from selected seed

*Five of these were small and weak.
†One of these was small.

were above ground at this date than of those grown from ordinary seed. In the case of those grown in frames, however, no advantage whatever was apparent. It seems fair to infer, therefore, that if any progress whatever has been made in increasing the hardiness of these beans, it has been so little as to be of no real practical value, which leads to the conclusion that this is not a promising line of plant-breeding.

Lawn Experiments.—The lawn experiment, begun in 1905, yielded some interesting results in 1906. The appearance of the sod in spring is recorded in the annual report for 1906. Later observations are given below.

The object of this experiment was to compare the effects of fertilizers leaving an acid residue and those leaving an alkaline residue with others which are nearly neutral in their effect on the soil. Seven different grasses and grass mixtures were used in this comparison. In addition to this, a number of plats designed to compare the influence of different proportions and combinations of fertilizers are included, also a number of partial plats which are seeded with additional special mixtures offered by seedsmen, or with individual grasses.

The following observations show the main features noted during the latter part of the season of 1906:

Acid Fertilizer.

Plat 1.—Kentucky bluegrass. A good, even lawn. An occasional chickweed and plantain appeared. Otherwise the plat was free from weeds. One of the best in color.

Plat 2.—Rhode Island bent. This made a turf of very fine and close texture. An occasional chickweed and a very few plants of plantain were the only weeds to be seen. Color objectionable, having a brownish appearance late in the season and in the early spring.

Plat No. 3.—Redtop. This grass makes a fair turf, but is much coarser in texture than bluegrass or Rhode Island bent. In color

it is better than Rhode Island bent, but not equal to Kentucky bluegrass.

Plat No. 4.—Red fescue. A number of vacant patches appeared in this plat. The seed was somewhat mixed with velvet grass, also known as meadow soft-grass, and these plants persist. Very few weeds appeared. The color is a peculiar gray, reminding one of the buffalo grass of the Plains, and giving a peculiar dried-up appearance to the lawn, especially when the rainfall is not abundant.

Plat No. 5.—Grass mixture No. 1; Kentucky bluegrass, Rhode Island bent, redtop, white clover, equal parts by weight. This gave a very nice even turf, with few weeds, and of excellent texture. The admixture of clover keeps it bright and fresh even in dry weather.

Plat No. 6.—Grass mixture No. 2; Rhode Island bent, redtop, red fescue. This gives a lawn good in texture, but not equal in this respect to Rhode Island bent used alone. It appears dry and brown in dry weather.

Plat No. 7.—Henderson's lawngrass. This mixture is largely made up of white clover and perennial rye grass, both of which keep green in dry weather, giving the lawn a good, fresh appearance at all seasons. The texture is somewhat coarse.

The different proportions and combinations of fertilizers tried showed no difference in effect during 1906.

The following notes were made upon the character of the different grass mixtures used:

Thorburn lawngrass.—This appeared coarse and uneven in texture. The clover seemed to be quite largely in patches. Some coarse grass which appeared like timothy was present.

Thorburn lawn-restoring mixture gave a good uniform turf, but very coarse in texture.

Thorburn putting-green mixture produced an even lawn with but few weeds, being about like redtop in texture.

Thorburn golf-links mixture gave a good, firm turf, moderately coarse in texture, with some clover present.

In Henderson's terrace-sod mixture clover was prominent, the texture being fairly good.

Henderson's tough-turf mixture gave an even, uniform turf, very good in texture, with clover abundant.

Creeping bent gave a very uneven lawn with many vacant spots, which were frequently occupied by sorrel and plantain. This is a very fine grass, giving a lawn of excellent texture where it is uniform. It starts early, thrives quite well in the shade, and is of a lighter green color than most of the grasses.

Canada bluegrass appeared somewhat patchy. The stubble is rather stiff, making the texture coarser than it appears to the eye. In color this grass is very dark, and unlike any of the others under experiment.

In comparing these same grasses on the plats treated with alkaline and neutral fertilizer, at the end of September the following observations were made:*

The Rhode Island bent plat treated with alkaline fertilizer was estimated to contain ten per cent. more chickweed and rather less plantain than the one treated with acid fertilizer. The redtop and red fescue were about alike in the three series. With grass mixture No. 1 the acid plat was very free from chickweed, which was quite abundant on the alkaline plat. There was also more plantain on the alkaline plat sown with mixture No. 2. With Henderson's mixture, no particular difference could be detected.

In color, Henderson's mixture, Thorburn's golf-links mixture, and Henderson's terrace-sod mixture rank first, all being quite similar in appearance, owing to the presence of perennial rye grass. Grass mixture No. 1 ranks next. Mixture No. 2 is dull, being about the poorest of any in appearance, with redtop and Canada bluegrass next in order, followed by creeping bent. The redtop lawn looks much like a hay-field shortly after mowing, the stubble being coarse.

Clover helps greatly in giving a fresh green appearance to a lawn in dry weather. Nearly all the grasses look brown during drought.

*It is possible that many of the weeds came from seeds already in the ground, which were unequally distributed.

Perennial rye grass is an exception, being the brightest of all. Kentucky bluegrass is also fairly good. Canada bluegrass gives the darkest lawn and creeping bent the lightest. Rhode Island bent gives a lighter colored lawn than Kentucky bluegrass.

After hard frosts occurred, redtop and grass mixture No. 2 appeared very brown. Henderson's mixture was still the best, followed by mixture No. 1, unless it were some of the special mixtures which contain perennial rye grass, as all of these held their color well. This grass and clover keep fresh and green in spite of the cold. Red fescue also looked better than most of the others late in the season, and much better than during the earlier dry weather. At the end of the season it appeared even better than bluegrass.

The finest grasses, like Rhode Island bent and red fescue, are harder to mow than the coarser kinds, like perennial rye grass and clover.

In the spring of 1907 marked differences were observed in the time at which the different mixtures and grasses began to make a presentable appearance. By the end of April most of the plats were beginning to look somewhat green, a few of them being quite presentable. Notes made April 22 show that Rhode Island bent appeared absolutely lifeless at that time, there being no green in sight except around the sides. The color in early spring is a very pronounced gray. This grass seemed to dominate the color of the plats sowed with mixture No. 1, so that they also looked gray. Red fescue also appeared gray, but with more of a yellowish tinge than the Rhode Island bent. Creeping bent also looks gray in early spring. Henderson's mixture becomes green very early, as both the white clover and the perennial rye grass start early. These grasses help the early appearance of the lawn wherever used.

By May 2 nearly all the plats were looking green. Those sowed with Rhode Island bent, or a mixture in which this formed a prominent part, still had a gray and dead appearance. This condition continued up to the middle of May. A note made May 14 states that the Rhode Island bent was really only just beginning to start

at that date.* The clover, rye grass, and bluegrass were then making a very good showing. Henderson's mixture appeared to be as good, already, as it would be at any time during the season.

A few days later the Rhode Island bent began to look fairly attractive, though the mat of dead grass still showed plainly. At that time the red fescue looked well, better than the bent.

By the end of May the Rhode Island bent gave a nice appearing lawn; in fact, at that time there was very little difference in the general appearance of any of the plats except in texture. So far as color and general appearance goes, they all looked well and much alike. Red fescue did have a little more of a gray look than the others, but the difference was not pronounced. Redtop is very coarse in texture and looks coarse at all times. It has nothing to recommend it as a lawn grass. The plats without clover were fully as pleasing at that date as those with it.

Market Garden Rotation.—This rotation was in the third year of the plan outlined, in 1906. The crops for the year consisted of potatoes and early cabbage for the early crops, which were followed by beets and carrots on the ground occupied by early cabbage and by turnips and cabbage on the ground first occupied by potatoes. The plan of the experiment, as explained in previous reports, is to compare stable-manure on the one hand with chemicals and a cover-crop on the other. Stable manure at the rate of ten cords per acre has been used annually on one plat, and chemicals at the rate of one ton per acre, upon the other, as follows:

Nitrate of soda, 400 pounds.
Dried blood, 300 pounds.
Acid phosphate, 1,000 pounds.
Muriate of potash, 300 pounds.

One-half the nitrate of soda and all of the other chemicals were mixed together for application at the time of planting, the remaining nitrate of soda being reserved for a later application.

* Had the grass been dressed with stable manure it would have started earlier.

New Queen potatoes, obtained from the Agronomy Division, were placed on shelves in a furnace room in the Experiment Station cellar to sprout, on April 4. These potatoes were of good size and in good condition. Stable manure was supplied to the plat receiving it, on April 9. The plats were plowed April 17. The rye cover-crop growing on the chemical plat was looking well, but somewhat bunchy; it was so large that it did not turn under well. A roller was then used on this plat, followed by a cutaway wheel harrow on both, though more harrowing was needed on the plat where rye was turned under. Half of the fertilizer, mixed as described above, was sown broadcast on the plat which receives chemicals, both plats then being harrowed with a spring-tooth harrow. The potatoes were planted on April 18. The remainder of the mixed fertilizer required on the one plat was applied in the furrow. A hand wheel-hoe was then run in each furrow to mix it with the soil. In order that conditions should be more uniform, this wheel-hoe was run through the furrows in the other plat in the same manner.

Five rows of potatoes were planted in each plat, these rows being about 208 feet long. The pieces were dropped fifteen inches apart in the row. Part of the seed was cut the afternoon before planting, the remainder on the day of planting. Rows were planted alternately on each plat.

Cabbage plants were set in the remaining three rows on each plat on April 23, the plants being placed eighteen inches apart. The weather conditions were excellent for transplanting.

The following table shows the dates on which cabbages were harvested, also the number of heads and the weights obtained:

	Chemical Plat.		Stable-Manure Plat.	
	No. of heads.	Weight.	No. of heads.	Weight.
July 9	88	265 lbs.	88	215 lbs.
July 14	22	81 "	22	83 "
July 16	4	14 "	...	....
July 21	275	1,070 "	282	1,070 "
Total	389	1,430 lbs.	392	1,368 lbs.

The above includes 90 bursted heads from the plat receiving chemicals, and 108 from the plat receiving stable manure.

It will be noted that chemicals produced a little larger yield than stable manure, this increase appearing chiefly at the first harvesting, indicating that the chemicals tended to hasten maturity.

Beets and carrots were sown, July 23, in the space from which the cabbages had been removed, two rows of carrots and three of beets being planted on each plat, with rows sixteen inches apart. These did not have time to complete their growth. While some very good beets of excellent usable size were obtained, the carrots were all small. They were harvested October 26, and the following weights were obtained:

	Weight of roots.	Weight of tops.
Beets grown with chemicals	270.5 lbs.	235 lbs.
Beets grown with stable manure	193.0 "	246 "
Carrots grown with chemicals	219.0 "	...
Carrots grown with stable manure	208.0 "	...

The carrots were so small that the tops and roots were not separated.

The potatoes were harvested August 9, and gave the following yields:

With Chemicals.

	Bushels.	Weight in Pounds.
Firsts	12.8	791
Seconds	2.5	165
Total	15.3	956

With Stable Manure.

	Bushels.	Weight in Pounds.
Firsts	14.5	904
Seconds	3.3	211
Total	17.8	1,115

This shows the yield of first quality potatoes to have been about fourteen per cent. greater from stable manure than from chemicals.

Four rows of turnips were planted and two rows of cabbage set, August 11, on the portion of each plat where potatoes had been growing. The remaining nitrate of soda was applied on this date to the plat receiving chemicals. These cabbages did not mature; they were harvested October 26. There being no heads worth considering, the plants were cut off at the ground and the whole top weighed. The weights thus obtained were as follows:

	Pounds.
Grown with chemicals	540
Grown with stable manure	588

The turnips were harvested November 19, 1906. While not large, many of them were excellent roots. The yields were as follows:

	Pounds of roots.	Pounds of tops.
Grown with chemicals	318	343
Grown with stable manure	330	280

Taking all the crops together, the returns from chemicals supplemented by cover-crops were fully equal to those obtained from stable manure, in the season of 1906, the only exception being that of the potatoes, which gave a slightly larger yield from stable manure.

In 1907 stable manure was applied to plat No. 101 on April 3. The land was plowed and harrowed April 17, the chemicals being applied on plat No. 102 on that date. Onions and spinach were sown on each plat, April 18.

Two rows of small lettuce plants were set soon after on each plat. The spinach germinated promptly, but the onions somewhat slowly. The lettuce made almost no growth, appearing very red and poor, being little larger by the middle of June than when set, due to the very cold, backward season.

By June 10 the spinach on the chemical plat was seen to be decidedly ahead, some of it being large enough to cut. In such a season as this chemicals ought to show an advantage, particularly where nitrate of soda is used, since in such cold, unfavorable weather the soil organisms are doubtless able to do little in rendering available the forms of nitrogen which stable manure contains.

Melons.—A simple experiment was carried on in 1906 to note the effect of methods of planting upon muskmelons, the particular object being to see whether it was possible to get a crop in spite of the melon blight. A strip of land which was used in the tent-covering experiment in 1905 was used for this purpose. The ground was plowed early in May, and lime applied and harrowed in at once, at the rate of one ton per acre.

On June 4 three furrows, 5½ feet apart, were plowed lengthwise of this strip, running the plow both ways to make the furrows deep. The plat was divided into three sections, each 69 feet 4 inches long. In sections 1 and 2 these furrows were partially filled, while in section 3 they were left as plowed. Stable manure was then placed in the furrows, using 980 pounds in each section. In sections 1 and 2 this was placed in the partially filled furrows, while in section 3 it was placed in the bottom as explained above. This manure was then covered by running a plow on each side of the furrows, which was followed by a cultivator and rake. This left a ridge covering each furrow in sections 1 and 2, with the ground entirely level in section 3.

It was designed to try methods of protecting the young plants in one of these sections, but this part of the experiment was not carried out, so that sections 1 and 2 are strictly comparable throughout. Seeds were planted in two-thirds of each row, in each section, the remainder of the row being left for potted plants. The potted plants were set June 6, having been started in three-inch pots May 1. These plants were set two feet apart in the row.

The first melons were harvested September 15, the numbers and weights harvested during the season being as follows:

	Section 1. From seed.		Section 1. Transplanted.		Section 2. From seed.		Section 2. Transplanted.		Section 3. From seed.		Section 3. Transplanted.	
	No.	Wt. (lbs.)	No.	Wt. (lbs.)	No.	Wt. (lbs.)	No.	Wt. (lbs.)	No.	Wt. (lbs.)	No.	Wt. (lbs.)
Sept. 15	0	0.0	2	1.5	6	5.3	5	7	3	2.0	24	30.0
Sept. 18	1	2.0	26	32.5	19	17.5	34	46	17	13.5	55	60.0
Sept. 20	10	8.0	24	29.0	46	36.5	10	7	78	65.0	31	28.5
Sept. 22	21	19.5	15	12.0	28	32.5	18	20	58	40.0	18	18.0
Sept. 25	30	24.0	19	19.0	55	43.0	16	18	62	46.0	22	12.0
Total.	62	53.5	86	94.0	154	134.8	83	98	218	166.5	150	148.5
Av. w'ts.	13.8 oz.		17.5 oz.		14 oz.		18.9 oz.		12.2 oz.		15.8 oz.	

These figures show that the largest melons were obtained from the transplanted plants, also that a larger proportion were obtained somewhat earlier. They also show that a better yield was obtained from the section in which the manure was placed in the bottom of the furrow and covered, leaving the ground level, than from the sections in which the furrows were partially filled and the melons planted on a ridge.

It being evident that only a small proportion of the melons could ripen, and as many of these might be taken, thus interfering with the record, all of those remaining on the vines September 19 were measured with calipers, the longer and shorter diameters being taken. The ones harvested September 20, 22, and 25, as given in the above table, are included in these measurements. The number and average diameter of melons found on each section at that date are shown below:

Section No.		Number of melons.	Average shortest diameter.	Average longest diameter.
1.	From seed	505	3.0	3.7
1.	Transplanted	190	3.4	4.1
2.	From seed	502	3.1	3.8
2.	Transplanted	156	3.5	4.1
3.	From seed	545	3.1	3.7
3.	Transplanted	165	3.2	3.9

It will be seen that here, as in the melons harvested and weighed,

those produced by transplanted plants were larger than those obtained from plants grown directly from seed. The transplanted plants in section 3 gave slightly smaller fruits than the transplanted ones in the other sections.

Comparing the number of melons produced from transplanted plants with those borne by plants grown directly from seed, we find the following:

Number borne by seed plants, 1,598.
Number borne by transplanted plants, 637.

There being twice as much space planted with seed as was set with plants, this shows the comparison for equal length of row to have been 637 from transplanted plants and 799 from seed plants. This does not, however, show the average production per plant, as the transplanted plants were set two feet apart in the row, while those grown from seed were naturally closer.

Blight made its appearance upon these melons toward the end of August, and the entire patch was sprayed with standard Bordeaux mixture on the afternoon of August 28. The vines were at that time strong and vigorous, but showed some blight, mostly in patches, and not very pronounced. This spraying was repeated September 4, one week later. The blight had made considerable progress since the previous spraying, some of the centers which showed at that time having become very pronounced, with most of the leaves dead. Spots of blight were to be seen all over the patch. A third spraying was given a week later, on September 11. The blight was then very bad, and apparently worst on the middle section. Certain spots were very pronounced. The vines were carrying a large number of melons, but needed more time to ripen them. A fourth spraying was given September 18. The vines were then drying up with blight in all sections, but the plants grown from seed in section 1 appeared to be in better condition than the others. While this method of spraying afforded no means of direct comparison, yet, judging from the rapidity with which plants usually die when at-

tacked by blight, and the behavior of melon plants elsewhere the same season, spraying did appear to hold the blight in check somewhat. Section No. 1 was really in quite fair condition at the date of this last spraying.

Another question which arose in connection with melon growing was whether growing plants might take from the soil copper sulfate in sufficient quantities to enable them to resist blight to any extent. This matter did not receive a very satisfactory test, but seeds were planted in frames and the plants watered with copper sulfate solution, as follows:

Plat 1. One pound copper sulfate to 100 gallons water.
Plat 2. Five pounds copper sulfate to 100 gallons water.
Plat 3. Ten pounds copper sulfate to 100 gallons water.

One gallon of the solution was applied to a spot of ground about four by six feet in area in each case. These applications were made August 1 and August 10. The vines in all three lots were almost entirely dead at the time of the second application, and soon perished completely. So far as this very crude test goes, therefore, it is not encouraging for this line of effort.

Strawberry Seedlings.—Detailed notes were made on the strawberries in fruit during the season of 1906. Very few of the named varieties gave satisfactory yields, Gowen's Seedling and Latest being the best. A few of the seedlings made a promising showing. The scores of some of these follow. The score of Senator Dunlap, as that of a typical popular variety at the present time, is added, also the scores of Gowen's Seedling and Latest representing the two which gave the best yields among the named varieties.

STRAWBERRY.

Variety...Senator Dunlap.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 8. Disease Resistance, 8. Frost Resistance.

FIG. 2. —PICKING EXPERIMENTAL STRAWBERRIES, 1907.

Fruit.

Productiveness, 6. Size, 7. Regularity, 8.5.
Appearance, 8. Texture, 7 (spongy). Quality, 7.5.
Fragrance. Rot Resistance.

DESCRIPTION.

Plant.

Leaves.
Runners, weak. Fruiting Stems, weak.
Bloom, Season, medium to late. Sex, perfect.

Fruit.

Form, ovate, flattened. Flavor, subacid, musky.
Color, new scarlet. Color of Flesh, new scarlet.
Calyx, raised. Core, solid.
Seeds, Position, prominent. Size. Color.
Season, First, June 19. Heaviest, June 19. Last, July, 2.
General Notes.
Yield from 10 plants, 157 ounces.

STRAWBERRY.

Variety..Gowen Seedling.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 8. Disease Resistance, 8. Frost Resistance.

Fruit.

Productiveness, 8. Size, 8.5. Regularity, 9.
Appearance, 9.5. Texture, 6.5. Quality, 7.
Fragrance. Rot Resistance, 8.

DESCRIPTION.

Plant.

Leaves, large, tall, dark, rugose, curled.
Runners, strong, few. Fruiting Stems, long, strong.
Bloom. Season. Sex.

Fruit.

Form, ovate. Flavor, subacid.
Color, opera scarlet. Color of Flesh, opera scarlet.

Calyx, close, large.
Core, spongy.
Seeds, Position, slightly depressed.
Size. Color, colored.
Season, First, June 19.
Heaviest, June 30. Last, July, 6.
General Notes.
Yield from about 10 plants, 222 ounces.

STRAWBERRY.

Variety...Latest.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 8. Disease Resistance, 8. Frost Resistance.

Fruit.

Productiveness, 8. Size, 8. Regularity, 8.
Appearance, 8. Texture, 7.5. Quality, 7.5.
Fragrance. Rot Resistance, 8.

DESCRIPTION.

Plant.

Leaves, dark.
Runners.
Fruiting Stems.
Bloom, Season.
Sex.

Fruit.

Form, irregular, ovate.
Flavor, subacid.
Color, opera scarlet.
Color of Flesh, opera scarlet.
Calyx, close.
Core, solid or spongy.
Seeds, Position.
Size, small. Color, light.
Season, First, June 19.
Heaviest, June 23. Last, July 6.
General Notes.
Yield from 10 plants, 265 ounces.

STRAWBERRY.

Variety...No. 239, Hunn X Ideal.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 8. Disease Resistance, 7. Frost Resistance.

Plant.

Productiveness, 8. Size, 8. Regularity, 8.
Appearance, 9. Texture, 6. Quality, 7.5.
Fragrance. Rot Resistance, 9.

DESCRIPTION.

Plant.

Leaves, large, tall, dark, rugose.
Runners, long, weak, few. Fruiting Stems, short, strong.
Bloom, Season. Sex.

Fruit.

Form, short conic. Flavor, subacid, musky.
Color, new scarlet. Color of Flesh, white, colored at margin.
Calyx, deeply depressed. Core, spongy.
Seeds, Position, raised. Size. Color, red.
Season, First, June 21. Heaviest, June 30. Last, July 6.
General Notes. Late. Just beginning to ripen well June 27. Stem photographed on that date. Form, color, and appearance excellent.
Yield from 10 plants, 69 ounces.

STRAWBERRY.

Variety....................................No. 243, Crescent X Glen Mary.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 7. Disease Resistance, 6. Frost Resistance.

Fruit.

Productiveness, 8. Size, 7.5. Regularity, 8.
Appearance, 7.5. Texture, 8.5. Quality, 7.5.
Fragrance. Rot Resistance, 8.

DESCRIPTION.

Plant.

Leaves, numerous, small, tall, light.
Runners, weak, numerous. Fruiting Stems, weak, short.
Bloom, Season, late. Sex, weakly perfect.

Fruit.

Form, ovate, flattened. Flavor, subacid.
Color, opera scarlet. Color of Flesh, opera scarlet.
Calyx, close. Core, solid.
Seeds, Position. Size. Color.
Season, First, June 19. Heaviest, June 30. Last, July 6.
General Notes. Productive, bright, but small.
Yield from 10 plants, 272½ ounces.

STRAWBERRY.

Variety..........................No. 248, McKinley X [Wm. Belt X Wild].

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 9. Disease Resistance, 7.5. Frost Resistance.

Fruit.

Productiveness, 7. Size, 7.5. Regularity, 8.
Appearance, 7.5. Texture, 8. Quality, 8.
Fragrance. Rot Resistance, 9.

DESCRIPTION.

Plant.

Leaves, numerous, tall, curled.
Runners, numerous, long. Fruiting Stems, short, weak.
Bloom, Season, medium. Sex, perfect.

Fruit.

Form, conic, flattened. Flavor, subacid.
Color, light. Color of Flesh, light.
Calyx, raised. Core, hollow.
Seeds, Position. Size. Color.
Season, First, June 19. Heaviest, June 30. Last, July 6.
General Notes. Large fruit for a wild cross. Light in color.
Yield from 10 plants, 180½ ounces.

STRAWBERRY.

Variety..........................No. 250, Glen Mary X [Bubach X Wilson].

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 9. Disease Resistance, 8. Frost Resistance.

FIG. 3.—SEEDLING NO. 239 (HUNN x IDEAL). Photographed June 27, 1906.

Fruit.

Productiveness, 7. Size, 7. Regularity, 8.
Appearance, 7.5. Texture, 7. Quality, 7.5.
Fragrance. Rot Resistance, 9.

DESCRIPTION.

Plant.

Leaves, few, large, tall, dark.
Runners, strong, long. Fruiting Stems, tall.
Bloom, Season, medium to late. Sex, perfect.

Fruit.

Form, ovate. Flavor, subacid.
Color, new scarlet. Color of Flesh, new scarlet, light.
Calyx, depressed. Core, spongy.
Seeds, Position. Size. Color.
Season, First, June 19. Heaviest, June 23. Last, July 6.
General Notes.
Yield from 10 plants, 293 ounces.

STRAWBERRY.

Variety..............................No. 251 [Wm. Belt X Wild] X McKinley.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 9. Disease Resistance, 7. Frost Resistance.

Fruit.

Productiveness, 7.5 Size, 7.5. Regularity, 8.
Appearance, 8. Texture, 8. Quality, 7.
Fragrance. Rot Resistance, 8.

DESCRIPTION.

Plant.

Leaves, tall, dark.
Runners, strong. Fruiting Stems, short, weak.
Bloom, Season. Sex.

Fruit.

Form, ovate. Flavor, subacid.
Color, opera scarlet. Color of Flesh, opera scarlet

Calyx, depressed. Core, spongy.
Seeds, Position. Size. Color.
Season, First, June 19. Heaviest, June 23. Last, July 6.
General Notes. Good.
Yield from 10 plants, 231½ ounces. Figured in annual report, 1905, p. 216, as No. 154–18.

STRAWBERRY.

Variety............................No. 254 [Wm. Belt X Wild] X McKinley.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 9. Disease Resistance, 7. Frost Resistance.

Fruit.

Productiveness, 7.5. Size, 7.5. Regularity, 7.
Appearance, 7. Texture, 7.5. Quality, 9.
Fragrance. Rot Resistance, 7.

DESCRIPTION.

Plant.

Leaves, numerous, tall, dark, slightly curled.
Runners, strong. Fruiting Stems, short, weak.
Bloom, Season, late. Sex, imperfect.

Fruit.

Form, ovate, flattened. Flavor, subacid, musky.
Color, opera scarlet. Color of Flesh, opera scarlet.
Calyx, raised. Core, hollow.
Seeds, Position, depressed. Size. Color.
Season, First, June 19. Heaviest, June 23. Last, July 6.
General Notes. A promising berry. Has the appearance of the wild berry, with good size, but not very much of the wild flavor.
Yield from 10 plants, 245½ ounces. Figured in annual report, 1905, p. 216, as 154–24.

STRAWBERRY.

Variety............................No. 255 [Wm. Belt X Wild] X McKinley.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 9. Disease Resistance, 8. Frost Resistance.

Fruit.

Productiveness, 8. Size, 7.5. Regularity, 7.5.
Appearance, 7. Texture, 7. Quality, 9.
Fragrance. Rot Resistance, 8.

DESCRIPTION.

Plant.

Leaves, small, dark, glossy.
Runners, numerous, weak. Fruiting Stems, weak.
Bloom, Season, medium. Sex, imperfect.

Fruit.

Form, ovate. Flavor, subacid.
Color, new scarlet. Color of Flesh, opera scarlet.
Calyx, raised. Core, hollow.
Seeds, Position. Size. Color.
Season, First, June 19. Heaviest, June 25. Last, July 6.
General Notes. Good plant, productive.
Yield from 10 plants, 242 ounces. Figured in annual report, 1905, p. 216, as 154-25.

STRAWBERRY.

Variety........................No. 257 [Bubach X Wm. Belt] X Glen Mary.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 8.5. Disease Resistance, 7.5. Frost Resistance.

Fruit.

Productiveness, 8. Size, 7. Regularity, 7.
Appearance, 8. Texture, 8. Quality, 8.
Fragrance. Rot Resistance.

DESCRIPTION.

Plant.

Leaves, few, dark, glossy.
Runners. Fruiting Stems, strong.
Bloom, Season, late. Sex, imperfect.

Fruit.

Form, ovate, flattened. Flavor, subacid.
Color, opera scarlet. Color of Flesh, light.

Calyx, close.
Core, solid.
Seeds, Position.
Size. Color.
Season, First.
Heaviest, June 30. Last, July 6.
General Notes. Late, productive.
Yield from 10 plants, 216*.

STRAWBERRY.

Variety........................No. 258 [Bubach X Wm. Belt] X Glen Mary.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 7.	Disease Resistance, 7.	Frost Resistance.

Fruit.

Productiveness, 9.	Size, 8.	Regularity, 7.5.
Appearance, 8.	Texture, 9.	Quality, 9.
Fragrance.	Rot Resistance, 8.	

Fruit.

Leaves, dark, curled.
Runners, few.
Fruiting Stems, short.
Bloom, Season, late.
Sex, imperfect.
Form, short, obtuse.
Flavor, subacid.
Color, opera scarlet.
Color of Flesh, light opera scarlet.
Calyx, depressed.
Core, solid.
Seeds, Position, depressed.
Size. Color.
Season, First, June 19.
Heaviest, June 30. Last, July 6.
General Notes. Late, productive, not very large, inclined to be irregular. Photographed in the field, June 27.
Yield from 10 plants, 210½ ounces.

STRAWBERRY.

Variety...........................No. 259, Glen Mary X [Bubach X Wilson].

SCALE-POINTS 10-Perfect.

Vigor, 8.5.	Disease Resistance, 7.	Frost Resistance.

Fruit.

Productiveness, 7.	Size, 7.5.	Regularity, 8.
Appearance, 8.	Texture, 8.5.	Quality, 8.5.
Fragrance.	Rot Resistance, 8.	

* Record of first picking not made.

Fig. 4.—Seedling No. 258 ([Buba x Wm. Belt] x Glen Mary).

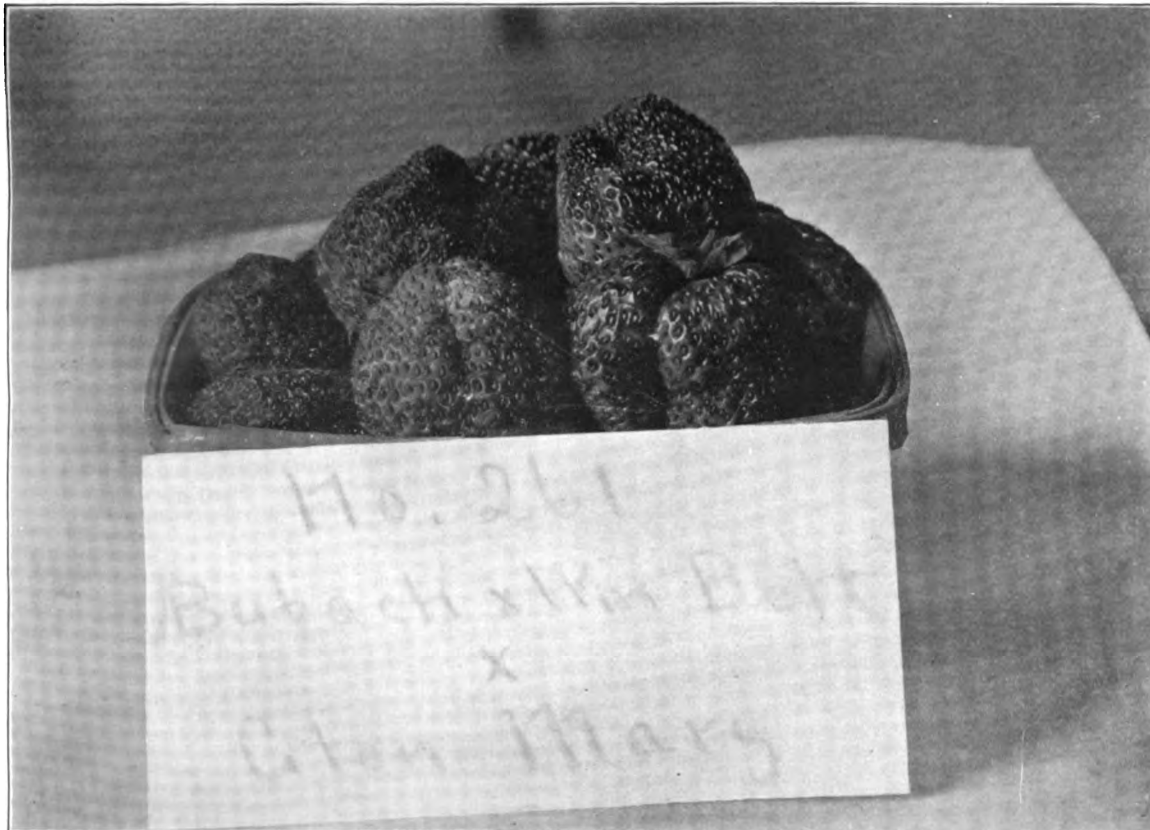


FIG. 5.—SEEDLING NO. 261 ([BUBA x WM. BELT] x GLEN MARY).

DESCRIPTION.

Plant.

Leaves, large, tall, dark, wrinkled.
Runners, long, strong. Fruiting Stems, short.
Bloom, Season, late. Sex, imperfect.

Fruit.

Form, ovate. Flavor, subacid.
Color, opera scarlet. Color of Flesh, opera scarlet.
Calyx, close, large. Core, spongy.
Seeds, Position. Size. Color, light.
Season, First, June 19. Heaviest, June 30. Last, July 6.
General Notes. Bright, attractive, of good quality. Flavor very pronounced, resembling pineapple.
Yield from 10 plants, 227 ounces.

STRAWBERRY.

Variety........................No. 261 [Bubach X Wm. Belt] X Glen Mary.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 7. Disease Resistance, 6. Frost Resistance.

Fruit.

Productiveness, 8.5. Size, 9. Regularity, 7.
Appearance, 7.5. Texture, 9. Quality, 7.5.
Fragrance. Rot Resistance, 9.

DESCRIPTION.

Plant.

Leaves, dark, curled.
Runners, few. Fruiting Stems, *short*, strong.
Bloom, Season, late. Sex, perfect.

Fruit.

Form, irregular, ovate, flattened. Flavor, subacid.
Color, opera scarlet. Color of Flesh, light.
Calyx, close or depressed. Core, solid.
Seeds, Position. Size. Color.

FIG. 4.—SEEDLING NO. 258 ([BUBA x WM. BELT] x GLEN MARY).

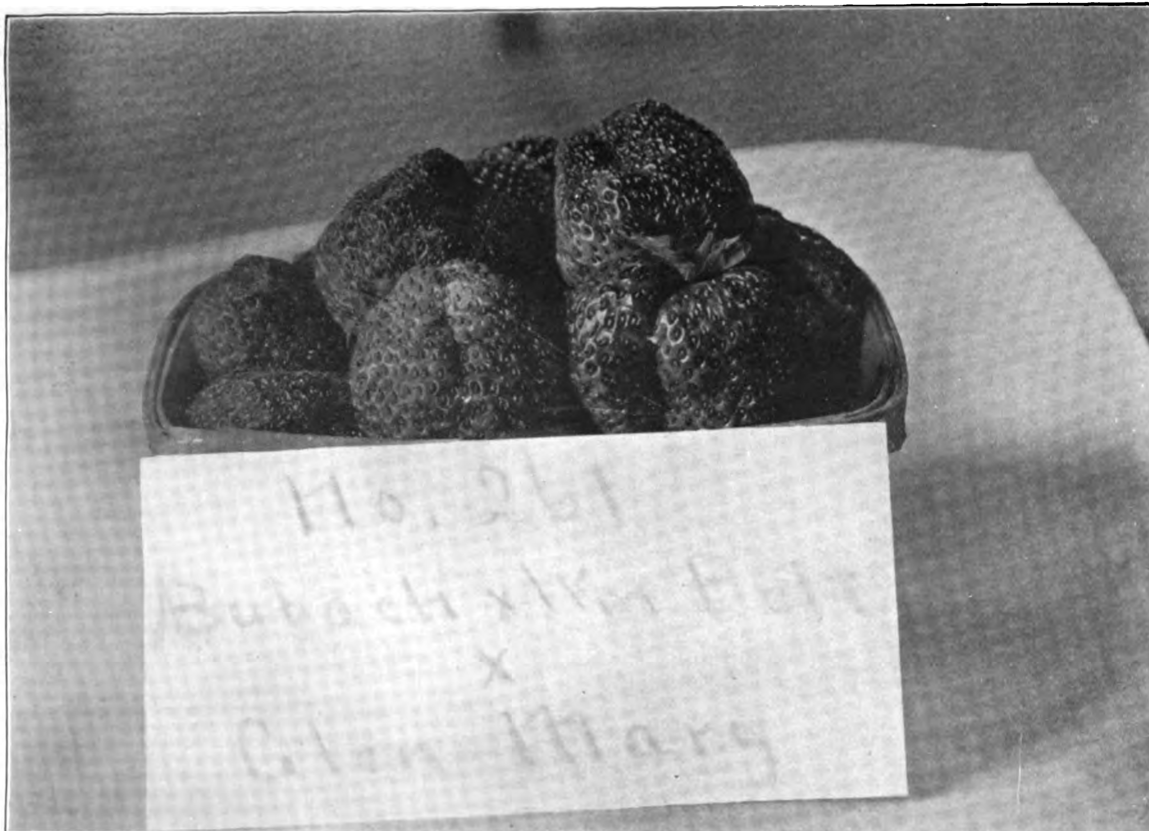


Fig. 5.—Seedling No. 261 ([Buba x Wm. Belt] x Glen Mary).

DESCRIPTION.

Plant.

Leaves, large, tall, dark, wrinkled.
Runners, long, strong. Fruiting Stems, short.
Bloom, Season, late. Sex, imperfect.

Fruit.

Form, ovate. Flavor, subacid.
Color, opera scarlet. Color of Flesh, opera scarlet.
Calyx; close, large. Core, spongy.
Seeds, Position. Size. Color, light.
Season, First, June 19. Heaviest, June 30. Last, July 6.
General Notes. Bright, attractive, of good quality. Flavor very pronounced, resembling pineapple.
Yield from 10 plants, 227 ounces.

STRAWBERRY.

Variety........................No. 261 [Bubach X Wm. Belt] X Glen Mary.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 7. Disease Resistance, 6. Frost Resistance.

Fruit.

Productiveness, 8.5. Size, 9. Regularity, 7.
Appearance, 7.5. Texture, 9. Quality, 7.5.
Fragrance. Rot Resistance, 9.

DESCRIPTION.

Plant.

Leaves, dark, curled.
Runners, few. Fruiting Stems, *short*, strong.
Bloom, Season, late. Sex, perfect.

Fruit.

Form, irregular, ovate, flattened. Flavor, subacid.
Color, opera scarlet. Color of Flesh, light.
Calyx, close or depressed. Core, solid.
Seeds, Position. Size. Color.

Season, First, June 19 (1 oz.). Heaviest, June 30. Last, July 6.
General Notes. Late, *promising*, some very fine, large berries.
Yield from 10 plants, 257 ounces.

STRAWBERRY.

Variety.................................No. 267 [Bubach X Wm. Belt] X Glen Mary.

SCALE-POINTS 10-Perfect.

Plant.

Vigor, 7.5. Disease Resistance, 8. Frost Resistance.

Fruit.

Productiveness, 9. Size, 7. Regularity, 7.
Appearance, 8. Texture, 7. Quality, 8.5.
Fragrance. Rot Resistance, 8.

DESCRIPTION.

Plant.

Leaves, few, tall, dark.
Runners, long, strong. Fruiting Stems, long, strong.
Bloom, Season, medium. Sex, imperfect.

Fruit.

Form, ovate. Flavor, musky.
Color, opera scarlet. Color of Flesh, light opera scarlet.
Calyx, close. Core, hollow.
Seeds, Position. Size. Color.
Season, First, June 19. Heaviest, June 23. Last, July 6.
General Notes. Late, productive.
Yield from 10 plants, 233½ ounces.

In the above scores the numerical scale-mark for productiveness represents the judgment of the observer, based upon appearances only as the plant is seen growing. This is not always a reliable guide, as may be seen by comparing these judgments with the yields obtained.

It will be seen that several of these seedlings which have descended in part from the wild strawberry gave very good yields.

Strawberry Selection.—In the year 1899 a number of varieties of

strawberries were in fruit on the College grounds. These were grown in hills, and the yield from each individual hill was recorded. These showed marked variations, some plants of the same varieties far exceeding others, with no apparent difference in conditions discernible. Taking this variation in yield as a basis, several varieties were selected with which to carry on experiments designed to determine whether it would be possible to increase productiveness by selecting plants continuously from the most productive parents. The following varieties were chosen for this purpose. The lowest, highest, and average yields of individual plants are also given to show the variation which occurred:

	Lowest yield in grams.	Highest yield in grams.	Average yield in grams.
Crescent	121.3	601.3	373.3
Glen Mary	286.6	756.3	460.1
Ideal	87.8	165.2	131.8
Jersey Market	67.0	491.8	284.0
McKinley	238.9	661 3	437.9
Parker Earle	72.6	469.2	285.0
Seaford	199.8	468.9	361.8
Yale	97.7	410.6	298.9

The most productive plant was chosen in each of these varieties. In the case of McKinley, a second plant, selected for large size and good shape of berries, with yield nearly as good as the best, was also chosen.

In 1900 young plants from each of these parents were selected for planting in a new location. Ten plants were taken in each case, if available. If not, other plants were set later when possible. The plan of that year was to allow each of these newly set plants to produce five runners with a single plant on each runner so that these younger plants could be transplanted the following spring and be ready to form a basis for continuing the selection as soon as the behavior of the plant from which they were taken could be known. The first difficulty encountered was the fact that the parents which had proved most productive in 1899 had often been so weakened by

their heavy fruit-bearing that they had produced but few plants, and these often weak. In order to remedy this difficulty, and also to provide for annual selection, the plan followed was to let each plant produce a few young ones in the year it was set, so that when its yield became known the following year plants would be already available with which to continue the selection, these young plants having been set in their permanent positions in the spring of the same year in which the parent plant bore its fruit. This was found, however, to be, in practice, somewhat more difficult to carry out than it would appear to be. If more than the desired number of plants are allowed to grow, their production weakens the parent plant, and without constant watchfulness it is almost impossible to get just the number needed and no more.

The first fruit was borne by these selection plants in 1901. The yields were much less than from the parent plants in 1899, due largely to the fact that some young plants had been produced so that not so good fruiting hills resulted. As before, the variations in yields were marked. The most productive plant was chosen from which to continue the selection. These, and the yields which they produced, were as follows:

	Yield in grams.
Crescent, 15–3*	209.
Glen Mary, 12–3	118.5
Ideal, 6–1	43.8
Jersey Market, 21–10	151.0
McKinley, 16–1	158.9
McKinley, 18–1	190.8
Seaford, 4–4	188.6
Yale, 20–4	138.6

In 1902 the yields were even poorer and more unsatisfactory than in 1901. This fact, however, does not argue anything either for or against the method of selection to increase yields; it means, rather,

*These designations mean that plant No. 15 of the Crescent variety gave the heaviest yield in 1899, and was the one chosen for selection, and that plant No. 3, of its offspring, yielded best in 1901, and was therefore chosen as the one through which to continue the selection.

as suggested above, that attempting to produce half a dozen plants from a single one, and then holding that parent plant to form a hill for fruiting the following year, is not a satisfactory procedure. Those which yielded best, however, were selected, as in previous years, and the plants for future setting were taken from the next generation which had been produced from these plants the year before fruiting.

Beginning with 1903 the plan was changed, and the plants set far enough apart so that each one might form a colony consisting of the plant set and the young plants produced from it. This permits taking the yield of the colony as a basis for selection, instead of the yield of the individual plant set. In this way the plants removed, from which to carry on the selection, have less effect in reducing the yield. It really seems to be a better basis of selection, too, since the majority of growers follow some of the matted-row systems, and the most satisfactory plant is the one which yields the most berries, not from its own stems, but from itself and its offspring together.

In this colony plan of selection five plants are set in a new location the first spring after planting, before the yield of the colony is known, in order that selection may go on from young vigorous plants and that yearly progress may be made, which could not be done if no plants were taken until after fruiting.

The yields in 1903 were even poorer than ever, due largely to the fact that too many runners had been allowed to form from the parent plants the previous autumn. However, those which gave the most fruit were chosen as the parents of the future line, in the same manner as before.

In 1904, the first year of colony fruiting, the yields were not altogether satisfactory, but afforded a better basis than by the previous plan. It was found, however, that it often depended more upon the number of plants which happened to remain in the colony than upon the individual productiveness of these plants. It is fair to assume, however, that this represents a part of the real value of the parent plant, and hence this colony plan has been steadily pursued since being started. A few of the varieties have done so poorly that they have been abandoned.

Detailed yields from these individual colonies would make tiresome reading, but the following table will show the highest, lowest, and average yield from the colonies of each variety in 1906:

	Lowest yield in grams.	Highest yield in grams.	Average yield in grams.
Crescent	27.0	118.5	66.7
Glen Mary	3.0	80.5	33.5
Ideal	4.0	31.0	14.0
McKinley	3.5	30.0	13.0

It is fair to ask, after the many years of selection, what progress has been made. Perhaps this question can only be answered fully by comparing these plants with those obtained from ordinary sources in the trade, which is now being done. So far as indications go, however, the result has not been promising. The difficulties which have appeared have seemed to more than offset the possible advantage which might accrue by always selecting the most productive parent. Indeed, in one case, when the old colonies were left a second year, the yield that year was not in the same order as the previous year when the line of selection was determined. This would, doubtless, often prove true. While strong, well-grown plants should always be preferred as parent stock, the indications are that choosing wholly from the standpoint of productiveness, like many other pretty theories, may readily be overworked.

MISCELLANEOUS EXPERIMENTS.

A number of problems have received attention during the connection of the horticulturist with the Station, many of which have yielded negative or comparatively unimportant results; others are of uch a nature that not sufficient time has elapsed to bring results. It seems well at this time to bring together most of these minor and long-time experiments, to record what has been accomplished.

Apple Breeding.—To determine, if possible, the influence of selecting cions from bearing trees of known quality and productiveness, twenty Northern Spy trees were planted in the spring of 1898. The

design was to top-graft ten of these with selected cions and ten from miscellaneous cions taken from nursery rows. Nine of these trees were whip-grafted, in the spring of 1899, with cions of Rhode Island Greening received from George T. Powell, of Ghent, New York. These cions were personally selected by Mr. Powell from typical trees bearing from seven to nine barrels each. Cions from ordinary nursery rows were not available. The other ten trees were therefore used from time to time for top-working with other varieties. These top-worked trees can be compared with nursery trees planted to determine more especially the influence of stock upon cion. These trees nearly all bloomed to some extent in 1907. A few hung full, but the majority of them had only a comparatively small number of blossoms.

For the purpose of determining more especially the influence of stock upon cion, five common nursery-grown trees of Rhode Island Greening and five trees of Newtown Pippin were planted in the spring of 1898, also ten trees of Northern Spy. One week after planting, these Northern Spy trees were grafted with cions from the Rhode Island Greening and Newtown Pippin. It is difficult to make cions live in a newly set tree, and only a few of these succeeded; but the trees all made a good growth. The Newtown Pippin trees had been double-worked in the nursery, thus interfering in part with the experiment. The following spring additional cions were set as needed. In all cases cions were taken from the nursery tree directly opposite the Northern Spy tree to be top-worked, except in the case of a few cions which were set in the year 1900, in which this precaution was overlooked. The trees in both of these experiments were growing close together, adjacent to those used in the experiment having to do with methods of pruning at planting time, when they were grafted. In the spring of 1900 they were moved to permanent positions in orchard land.

Rhode Island Greening tree No. 1 and Newtown Pippin tree No. 5, as bought from the nursery, died and were replaced by other trees ordered from the nursery in the spring of 1902. Newtown Pippin

tree No. 1 and No. 5 also had to be replaced in 1905; consequently, as at present growing, these trees are younger than the others.

In working among the trees it has been noticed that the stock has no apparent effect in retarding leaf-growth. The Northern Spy is a variety which puts out its leaves late, but the Greening and Newtown top-worked on the Spy appear to be as forward as those bought from the nursery, while the Spy itself is considerably behind both of the others.

Several of the trees top-worked with Rhode Island Greening bore a few specimens in 1905. Only one of the Rhode Island Greening trees as ordered from the nursery and planted at the same time bore any fruit; that had a single apple. In the case of the top-worked tree which bore most, the tree opposite, from which the cions came bore no fruit.

In 1906 one of the top-worked Rhode Island Greening trees blossomed full; others, both top-worked and nursery trees, bore only a few scattered blossoms. Only one tree of Newtown Pippin blossomed to any extent; this was one which was planted on its own roots. Several of the others bore a few scattered blossoms.

In 1907 the Newtown Pippin trees on their own roots have shown as much bloom, on the average, as those top-worked. One of the top-worked Rhode Island Greening trees blossomed very full. One on its own roots also bloomed well. No marked difference was observed between the others, but apparently the top-worked trees had rather more bloom than the others, if there was any difference.

So far as these trees afford evidence, therefore, the indications are that top-working does not retard the bearing period, but rather appears to hasten it. The Newtown Pippin trees top-worked on Spy are all uniform and satisfactory trees; of the others, two have been replaced as noted above. The remainder are nearly as good trees as those top-worked. No difference in habit of growth, in either variety can be detected between those top-worked and those as purchased from the nursery.

Apple Fertilizer.—In 1904 some of the apple trees in the College

orchard bore undersized fruit, even when the yield was light. Only a moderate amount of fertilizer has been used in this orchard from year to year, the rate per acre having been approximately the following:

100 lbs. nitrate soda
100 " dried blood.
100 " tankage.
100 " acid phosphate.
100 " muriate potash.

It was therefore thought that perhaps the trees were not receiving enough nitrogen; accordingly five trees of different varieties were selected, to each of which five pounds of nitrate of soda were applied, in addition to this regular fertilizer formula. This was repeated in 1906, but no immediate effect could be noted in the appearance of the trees or the fruit in either case. Trees were not available to make definite comparisons of yields. A later suggestion which occurred to the assistant in charge was that this small fruit in 1904 might have been due to the action of plant-lice, which were very abundant that season.

Asters.—The practice of sowing asters in the fall is sometimes recommended. A single attempt to compare fall-sown with spring-sown seed was made by sowing seed of a number of varieties in the fall of 1902 and reserving part of the seed for sowing the following spring. None of those sown in the fall came up well enough to permit making a comparison. Those sown in spring also made a poor growth, doubtless due in part to the fact that the seed of necessity was then old.

Odd-Year Baldwin.—The Baldwin apple is notably a biennial bearer, yielding heavy crops in alternate years with very little fruit the other seasons. From time to time reports are seen of trees or orchards which are said to bear in the off year. If that habit could be perpetuated in young trees it would prove of decided commercial benefit. In order to test the matter, cions were received from several sources in the spring of 1902.

From Edward Van Alstyne, Kinderhook, New York, cions from trees which bore in 1901 were received, and others from trees which should bear in 1902; 1901 was the odd Baldwin year. Both sorts of cions were grafted in young trees in the orchard, and also in old bearing trees.

Cions from a tree said to bear in the odd year were also received from H. R. Marden, Brookline, Mass. A young tree was grafted with these, and some were also set in a bearing tree.

Still other cions which were being offered as an odd-year Baldwin were received from J. W. Adams & Company, Springfield, Mass., a part of which were set in a young tree and part in a bearing tree as with the others. Of those set in bearing trees, one stub of the Marden cions hung full of fruit in 1905; but this had been injured at the union, which may account for its fruiting, as the other cion bore none. A little fruit was borne by the Adams cion. One in the same tree, taken from a Baldwin tree on the College ground, had a single apple; the other from this source bore none. None of the Van Alstyne cions of either sort bore. The trees in which all of these cions were set are Baldwins and were bearing a good crop.

None of these cions bore in 1906. Those set in young trees have not yet reached bearing age.

Beans, Crossing.—Both in 1905 and 1906 a few attempts were made to cross the English Broad bean (*Vicia faba*) with common garden bush beans, in order to determine if the hardiness of the English bean may be incorporated with garden varieties.

Bean flowers are difficult to manipulate, and the attempt in both cases met with failure.

Blooming Period.—Records of the blooming period of fruit trees in the College orchard for the years 1899, 1901, 1902, and 1903 appear in the annual report for the year 1903. Similar records have been kept since for at least a portion of the varieties.

In looking these over it appears that the greatest variation in season has amounted to about twelve days, the year 1903 being the earliest season and 1901 the latest, with 1899 nearly as late. The

duration of blooming period is usually about twelve to fifteen days with apples, cherries, and pears; with plums it is slightly less, usually about ten days. The greatest variation in different varieties in the same season has usually been about eight days with apples, though in extreme cases it has been as much as two weeks. This is a matter of considerable importance in spraying an orchard made up of many varieties.

The following table will show when the leaf-buds began to open and the date of bloom of a few leading varieties for the years 1904, 1905, and 1907. Owing to the failure of an assistant to carry out instructions, records are not available for 1906:

APPLE.

	Opening of leaf-buds.			First bloom.			Full bloom.		
	1904	1905	1907	1904	1905	1907	1904	1905	1907
Baldwin	May 4	......	May 1	......	May 17	May 20	......	......	June 3
Ben Davis	May 4	May 4	......	May 17	May 18	......	May 21	May 25	......
Early Harvest	May 4	......	May 6	May 13	......	May 20	May 20	......	June 3
Northern Spy	May 10	......	May 9	May 20	......	May 25	......	......	June 3
Ralls	May 5	......	......	May 19	......	......	May 25	......	......
Red Astrachan	May 4	May 2	May 1	May 15	May 17	May 19	May 20	May 25	May 23
Roxbury (russet)	May 2	May 3	May 6	May 14	May 16	May 20	May 19	May 22	June 5
Winesap	May 5	......	May 6	May 18	......	May 29	May 24	......	June 4
Yellow Transparent	May 4	......	May 10	May 14	......	No bloom.	May 19	......	......

PEAR.

	1904	1905	1907	1904	1905	1907	1904	1905	1907
Anjou	May 4	May 9	May 7	May 12	May 12	May 18	May 19	May 16	May 22
Bartlett	May 7	May 7	May 1	May 15	May 12	May 18	May 20	May 15	May 20
Clairgeau	May 9	May 11	May 6	May 16	May 12	May 20	May 19	May 15	May 24
Kieffer	May 5	May 10	May 5	May 11	May 12	May 18	May 17	May 16	May 22
Louise (Bonne de Jersey)	May 7	May 10	May 7	May 12	May 13	May 18	May 18	May 17	May 22
Seckel	May 6	May 8	May 5	May 14	May 13	May 18	May 18	May 16	May 21
Sheldon	May 5	May 11	May 5	May 12	May 12	May 18	May 18	May 16	May 21
Winter Nelis	May 7	May 19	May 8	May 16	May 21	May 23	May 19	May 26	May 27

PEACH.

	Opening of leaf-buds.			First bloom.			Full bloom.		
	1904	1905	1907	1904	1905	1907	1904	1905	1907
Chairs	......	......	......	......	May 8	......	......	May 10	......
Champion	......	......	May 6	......	May 9	May 17	......	May 10	May 20
Chili (Hills)	May 5	......	......	May 10	May 8	......	May 16	May 11	......
Crawford, Late	......	......	May 6	......	May 7	May 17	......	May 10	May 20
Elberta	May 4	......	......	May 10	May 9	......	May 16	May 16	......
Mountain Rose	......	......	......	......	May 9	......	......	May 11	......
Oldmixon	May 4	......	May 6	May 10	May 7	May 17	May 16	May 10	May 21
Rivers (Early)	May 5	......	May 6	May 11	May 9	May 14	May 16	May 11	May 20

PLUM.

	Opening of leaf-buds.			First bloom.			Full bloom.		
	1904	1905	1907	1904	1905	1907	1904	1905	1907
Abundance	May 4	......	......	May 10	......	......	May 17	......	......
Burbank	May 6	May 2	......	May 8	......	......	May 18	......	......
German Prune	......	May 11	......	......	May 12	......	......	May 25	......
Gueii	......	May 8	......	......	May 9	......	......	May 14	......
Wickson	May 8	......	......	May 10	......	......	May 18	......	......
Wild Goose	May 7	May 8	......	May 13	May 12	......	May 18	......	......

Buffalo Berry.—An attempt was made to grow the Buffalo berry of the western plains among the bush-fruits in the College garden. Although the plants were merely heeled-in in the nursery the first season, nearly all of them lived and made a good growth. When transplanted to permanent rows, however, they very soon disappeared, showing their lack of adaptability to our moist eastern climate.

Bush-Fruit Selection.—From time to time promising forms of raspberry and blackberry have been noted and attempts made to perpetuate them, thinking that thereby an improved strain might be secured. In the case of the black raspberry, as noted in Bulletin No. 91, plants which bore heavily were selected for the same purpose. All of these attempts have yielded unsatisfactory results. In the case of the red raspberry and blackberry the first difficulty comes in securing suckers which are known to be from the roots of the plant chosen. A further difficulty arises in attempting to keep these pure unless set wholly by themselves in some part of the field, which was not done in these tests. We find that suckers frequently spring up even in the second row from where the plants are grown, so that it is very difficult to keep varieties distinct under any ordinary conditions. In the case of the black raspberries the trouble came in securing young plants. It is not easy to get old black-cap plants to root at the tips, and not enough plants were secured to carry out the plan of selection.

Our trials have not been made with the thoroughness which they deserve; but so far as they have given us indications, these indications have not been very promising for this line of work, either with bush-fruits or with strawberries.

Cherry Crosses.—Numerous attempts have been made during different years to secure crosses between the sweet and sour cherry, in the hope of securing the qualities of the sweet cherry with a tree better adopted to our conditions; one which should prove hardier, longer lived, and more productive. No trees have been secured as a result of this work.

A number of fruits have been obtained which appeared to be normal, and others in which the outside fruit and stone were developed, but with the cavity within the stone hollow or only partially filled. The best results have been obtained by crossing blossoms of the sour cherry with pollen from a sweet cherry; in fact, all the promising seeds have been produced by this combination.

In 1900 two seeds of Montmorency Empress Eugenia germinated. One of these young plants was unfortunately broken in transferring it, and the other perished after being planted in the open ground. No immediate influence of the pollen has been observed in any of the work.

A few attempts were made to cross the Montmorency sour cherry with the sand cherry. In nearly all cases the resulting pits had no germ inside, though in one case a seed was cut open enough to show that the cavity was apparently filled with a living kernel, but no plant was obtained.

Enough has been done to show that it is possible to cross these two classes of cherries, although many failures are likely to result in the attempt.

Color of Fruit.—In connection with the influence of the stock upon the cion the question arises whether the color of fruit borne by the stock may have any influence upon the color of fruit borne by the cion. To throw some light upon this question cions of Primate apple were grafted into Early Harvest and Red June trees in 1900. Additional cions were set in 1901 and 1902. In so far as possible these were given approximately similar locations in each tree, and in the majority of cases a cion was divided, placing part in one tree and part in the other. All of the cions came from the same Primate tree.

The Primate is an apple which normally shows a faint red blush upon its cheek; it was chosen for this reason, thinking that it might possibly show the influence of the bright red color of the Red June and the absence of red from the Early Harvest, if any such influence

exists. Thus far these cions have not borne sufficient fruit to answer the question.

Currant Leaf-spot.—A single observation upon the ability of the different varieties of currants to resist the fungous diseases which cause the premature falling of the leaves is of interest. The observation was made September 9, 1905. The Franco-German currant was then holding its leaves much better than the others, being in a very fair condition; this is a very late variety, with small fruit. The Pomona and White Imperial were leafless at the time. The Perfection, Comet, and Wilder were holding their leaves moderately well. On a single plant of Filler the leaves were remaining well, but had dropped from the others.

The Gooseberries were all nearly leafless, the Pearl holding its leaves better than the others.

The Pomona and Franco-German currants were side by side and were photographed.

Huckleberries.—Various experiments in attempting to propagate and grow the common blueberry of New England (*Vaccinium corymbosum*) have been recorded in the annual reports. Recently no definite experiments in propagation have been carried on. One row of plants has remained growing in the Station grounds. The greater part of these were plants transferred directly from the fields; others have been propagated in various ways. A number of those from the field have proved to be the form which bears early, small, black fruit. This is an undesirable type or species. The typical form bears large, blue berries, somewhat later in the season. These plants were somewhat slow in gaining a foothold, but at present appear to be thoroughly established and very much at home, making a satisfactory growth in every way, showing that under our soil conditions there is no difficulty in growing this plant under cultivation. The land has been constantly cultivated in the same manner as that planted with other bush-fruits, a cover-crop usually being sowed in midsummer. So far as one can judge by the appearance of the fruit, without having plants of the same parentage growing wild with

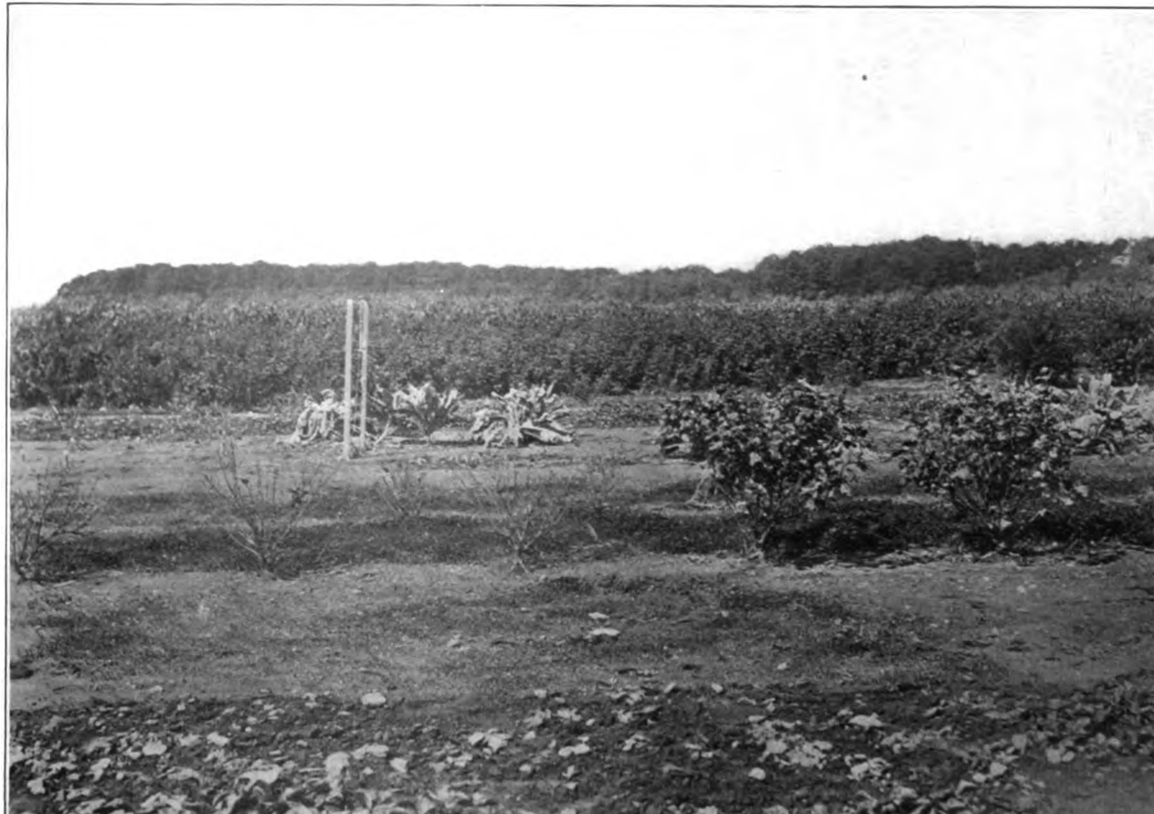


Fig. 6.—Pomona and Franco German Currants Showing Effect of Leaf-Spot.

which to compare, there has been no increase in the size of the fruit under cultivation, nor in the productiveness of the plants. This should not be accepted as a general statement that no such improvement will occur, but it seems to have been the case with these plants.

The blueberry is such a desirable fruit that it ought to be more generally grown about the home grounds. While it is slow in growth, it requires little care and may well repay the slight attention demanded.

Ilex Crosses.—Two beautiful species of Ilex are common in the fields of New England. The winter-berry, *Ilex verticillata,* which holds its bright red fruit well into the winter, and *Ilex glabra,* which bears black fruit, but holds its leaves bright and green throughout the winter. If the red fruit of the one could be as abundantly produced among the green foliage of the other as it normally is in the leafless species, we should have a most pleasing ornamental shrub. A number of attempts have been made to cross the two species, but in every case without result. Mention is made of some of these attempts in the annual report for 1903. As a practical means of securing much the same effect the two species may be planted together in such close contact that the red berries are intermingled with the green leaves and an excellent result obtained.

Peach Varieties.—Brief notes made upon a few varieties of peaches which have fruited upon the College grounds may be of interest. The unusually cold winter of 1893–4 killed most of the buds. Many trees bore no fruit whatever, and most of the others only a very few specimens.

Rivers (Early) bore a fair number of good-sized, fine-flavored fruits, juicy, rather pale in color, with very little rot. This is a white-fleshed peach, which is considered hardy and of excellent quality, though rather too tender to ship well.

Bokara No. 3 bore no fruit, not maintaining its reputation for hardiness.

Mountain Rose. One tree bore a fairly good crop, the others,

scattering fruits. This is a white peach of good color, excellent quality, and fair size.

Fitzgerald bore a few fruits; size medium or below, fragrant; color, excellent. Comparing this with Elberta, the flesh is higher colored, more juicy and fragrant, and of much better flavor. The pit of Fitzgerald is very small, so that the flesh is as thick as on Elberta, though the fruit is smaller. The quality of Fitzgerald is high, but it would not ship as well as Elberta.

Oldmixon bore a few good fruits. This is a white peach which usually proves reliable here.

Elberta bore a few fruits; size good, color deficient. The fruit was blown off quite badly by the wind.

Chili (Hills) bore a few scattering fruits.

Champion bore a few fruits. This is a very juicy, white peach of excellent quality.

Dewey bore a few fruits of high color and small size, ripening early.

Chairs, Crawford Late, St. John, and Stevens bore no fruit, or not enough to afford comparison.

These notes are given in detail because showing something of the hardiness of the different varieties. Notes on the following varieties were made in 1905.

Waddell. A fine looking, high colored peach of medium size, just ripening August 30. Flesh white throughout and very juicy; flavor not good, in fact, deficient; clings to the stone considerably; stone of light color and medium size. A very attractive peach, apparently bearing well for the age of the trees.

Yellow St. John. Scarcely ripe at the middle of September, but apparently a little ahead of other yellow varieties; size good and color promising, though picked a little green; flesh yellow, juicy, but apparently fairly firm; flavor and quality good; bearing only a light crop.

The location chosen for the new greenhouse has unfortunately caused the sacrifice of the greater portion of our peach trees just as they were reaching their best bearing age.

Treatment Designed to Add to the Durability of Posts.—In the annual report for 1903 the methods of treatment applied to posts in the College vineyard are recorded. No observations upon them were made until the autumn of 1906. It is still too soon to expect any definite results, but the following notes may be of interest. The treatment of the ends set in the ground was as follows:

Row 1. Untreated.
Row 2. Charred; the end of the post set in the ground being placed over a fire until thoroughly black and somewhat burnt.
Row 3. Painted with coal-tar.
Row 4. Painted with hot pine-tar.
Row 5. Treated with lime, by placing the posts in a hole with fresh lime in the bottom and among the crevices between the posts, water being added to slake the lime.
Row 6. Copperas and limewater. The posts were allowed to soak over night in a solution of copperas, and then to stand some time in limewater.
Row 7. Carbolineum.

Part of the posts in each row were set with the bottom end down and part with the top end down. Six posts in each row were examined in the fall of 1906. Those treated with carbolineum then made the best showing. In nearly all of these a shell of the outside surface still remained, and in some cases this appeared to be quite firm. Those charred and the ones treated with coal-tar appeared to rank next in their condition of preservation, there being little to choose between them. With the untreated posts all of the last year's growth of wood had decayed away. In the others this had decayed, but in many cases more or less of a shell remained on the outside. Very little difference could be detected between those treated with pine-tar, lime, or copperas and lime; the last year's growth was decayed in all of these cases, and usually not much of a shell was left.

No difference could be detected between the posts set with the top end down and those with the bottom end down. Appearances

indicated that a deeper charring would have been the most promising method, unless it were the treatment with carbolineum, which certainly appeared to lead at the time the examination was made.

Methods of Tree Planting.—In the spring of 1898 ten Northern Spy apple trees were planted by different methods, in order to test the influence of methods of pruning at planting time upon the subsequent growth. The results apparent at the time were given in the annual report for 1898. Recently this strip of land has been in use by the poultry department, and the trees have had no attention; but their appearance at the present time is of interest.

The methods of pruning, were as follows:

1. Trees obtained from the nursery as two-year whips.

2. Two-year branched trees trimmed to a whip when set.

3. Two-year trees with branches cut back one-half, the leader being left untouched.

4. Two-year trees untrimmed.

In the above lots the roots were left untrimmed unless injured or decayed at the end, in which case they were cut back to sound wood.

5. Roots untrimmed.

6. Roots cut back half.

7. Roots cut back by the Stringfellow method, leaving only a mere stump.

In these three lots the branches were cut back about one-half, leaving the leader untouched.

8. Stringfellow method, the roots being cut back to a mere stump one or two inches long, and the tops cut back to a stub about one foot long.

At the present time the trees treated by the Stringfellow method are excellent, with the exception of one or two which stand near a pasture fence and may have been injured. The others are nearly as tall as the trees which were trimmed high when planted, and have a good development of branches, though apparently not greater than that shown by the tops of some of the trees treated in other ways.

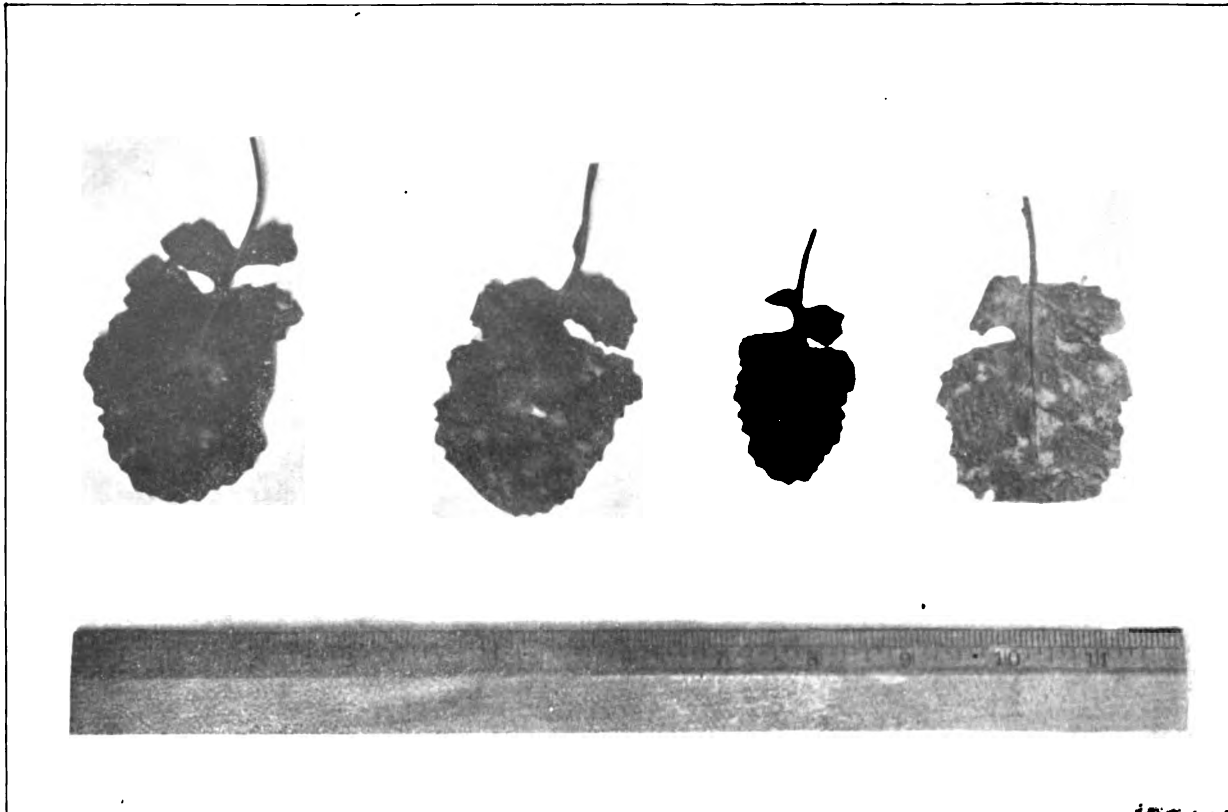


FIG. 7.—DOWNY MILDEW.

Among all the others it is impossible to single out any one lot as noticeably different from the rest, except the limbed trees which were trimmed to whips when set. Three of these are good trees, fully up to the average, but the others are decidedly poorer than those treated in other ways. The tendency has been to develop a tall, leggy growth, with small tops.

The trees which were not trimmed at all when planted are excellent, as are also those which had the roots cut away with the branches only shortened about one-half. Some of these are among the best trees in the whole experiment.

The results seem to indicate now, as earlier, that in the moist Rhode Island climate no more trimming is desirable for apple trees at planting time than is necessary to enable the tree to start into growth well, and under favorable conditions that means very little. The plan of shortening back the side branches somewhat and leaving the roots untrimmed, unless injured, appears to be one of the best.

AN EXPERIMENT IN SWEDISH TURNIP CULTURE.

The following experiment with Swedish turnips was carried out by Harry R. Lewis, a student in the senior class of 1907, as College work, being registered under course No. 13 in agriculture, designated as "Original Investigation." This piece of work was well done, and gives useful suggestions regarding the conditions likely to produce best results in turnip culture. The results, as reported by him, follow.

The Experiment.

The turnip, being one of our staple crops, has received a great deal of attention as to cultural methods, fertilizers, etc. The experiment stations of this country and Europe have spent much time experimenting with it, and consequently there is much scientific and popular literature on the subject. In all this work no reference has been found to the variation in the character of the root system.

Some seasons and in some locations the root will be perfect in shape, well formed and full, with only one or two tap roots, and free from numerous smaller crooked roots which injure its appearance, also its salability and keeping qualities. The special object of this work has been to determine, if possible, the effects of moisture, fertilizers, and different kinds of soil on variations of the root system. Also the effect of different fertilizers and combinations of fertilizers upon root and top growth have been noticed, and some interesting results have been obtained.

The variety of turnip used was Budlong's White Rock. The seeds were planted in a cold-frame, October 2; they germinated October 7, with an excellent per cent. of germination. No manure of any kind was used in growing the seedlings. On the night of October 24 the temperature fell so low that the leaves were frozen, and icicles hung from the ends where they had transpired during the night. They were given plenty of air and allowed to thaw out gradually, and no damage seemed to have been done.

On November 15 the seedlings were transplanted to the greenhouse. A bed was used which was 18 inches high and about 45 feet long. It was half filled with stones, and then the upper half divided into 36 separate plats. The young plants stood the transplanting remarkably well, and growth started uniformly. Nine plants were set in each plat, about 8 inches apart. The following amount of fertilizer per acre was applied in every instance, when used:

50 lbs. actual potash.
50 lbs. actual nitrogen.
75 lbs. actual phosphoric acid.
10 cords stable manure.
1 ton lime.
1,000 lbs. ashes.

The potash was applied in every case in muriate of potash, the phosphoric acid was applied in acid phosphate, while the nitrogen was applied in various materials.

The soils used in the experiment were as follows:

1. Sandy. This was made by mixing clean sand with garden soil in equal proportions.

2. Garden soil. This was simply soil taken from the College garden.

3. Humus. This was really leaf-mold obtained from a forest, and was consequently decidedly acid.

4. Silt loam sub-soil. This was a sub-soil of fine texture approaching clay, though it was a silt loam.

The plants grew remarkably well until December 3, when white spots were noticed on many of the leaves. Upon microscopic examination it was found to be a downy mildew, known as *Peronospora parasitica.* This is a mildew which is found quite extensively in Great Britain and the United States. It produces a greater or less deformation of the attacked stems and leaves of many wild and cultivated *Cruciferæ.* Among the cultivated plants most liable to injury are the turnip, cabbage, radish, rape, and cress. This fungus winters in the soil and in the old dried leaves of affected plants. Damp weather is especially favorable to its rapid growth. It was first noticed on December 3, and by December 7 about 25 to 30 per cent. of the plants were affected to a greater or less extent. Spraying with Bordeaux mixture was attempted, but owing to the peculiar smoothness of the leaves the solution failed to adhere to them. With the coming of bright sunny weather on December 11 the disease received a decided check, and from that time on caused no serious trouble. As the plants increased in size and age it gradually disappeared. Fig. 7 shows the appearance of the fungus on the leaves when it was at its height. A badly affected plant receives a serious setback.

During the period of growth quite a variation was noted in the development of tops. A few of the most marked differences only can be mentioned here. On January 9, 1907, the following results were noted: The tops on plats 1 and 2* were about even, but showed a marked advance over those on Nos. 3 and 4. Upon plats

* See following page for explanation of plate used.

5, 6, 7, and 8, in every case, excepting the humous soil (plat 7), lime seemed to be detrimental rather than helpful. The advantage of plat 7 over plat 3 was slight, but yet enough to warrant the application of lime to this humous soil.

The section where phosphoric acid and potash were used was far ahead of the one where nitrogen and potash were applied. In sections 5, 6, and 7 no decided difference was noticed, showing that as far as the tops were concerned it was immaterial whether the nitrogen was applied in dried blood, nitrate of soda, or ammonium sulfate (the same thing as sulfate of ammonia). In section 9, where ashes were used, there was not found as good a growth of tops as in section 8, where stable manure was used.

Plats 29, 30, 31, and 32 were ahead of plats 17, 18, 19, and 20. This would tend to show that the lime was beneficial when used in connection with the chemical manures. Section 11, which was treated exactly like section 10, except for being kept very moist, was a little ahead in growth of tops.

On April 4, 5, and 6 the different plats were harvested, the tops and bottoms were weighed, and any noticeable differences in growth were photographed.

The table of weights is given below:

SECTION I.

Plat No.	Kind of soil.	Manures.	Weight of roots. Pounds.	Weight of tops. Pounds.
1	Sandy Soil.	Untreated.	2.38	1.67
2	Garden Soil.		3.00	2.03
3	Humus Soil.		1.88	1.02
4	Silt Loam Subsoil.		2.11	1.92

SECTION II.

Plat No.	Kind of soil.	Manures.	Weight of roots. Pounds.	Weight of tops. Pounds.
5	Sandy Soil.	Lime.	1.94	1.34
6	Garden Soil.		2.00	1.88
7	Humus Soil.		2.55	1.59
8	Silt Loam Subsoil.		2.23	2.38

SECTION III.

Plat No.	Kind of soil.	Manures.	Weight of roots. Pounds.	Weight of tops. Pounds.
9	Sandy Soil.	Nitrate of Soda. Muriate of Potash.	1.73	1.95
10	Garden Soil.		3.16	3.50
11	Humus Soil.		3.14	3.61
12	Silt Loam Subsoil.		1.75	2.13

SECTION IV.

Plat No.	Kind of soil.	Manures.	Weight of roots. Pounds.	Weight of tops. Pounds.
13	Sandy Soil.	Acid Phosphate. Muriate of Potash.	2.63	2.63
14	Garden Soil.		3.33	3.48
15	Humus Soil.		2.55	2.42
16	Silt Loam Subsoil.		3.53	3.42

SECTION V.

Plat No.	Kind of soil.	Manures.	Weight of roots. Pounds.	Weight of tops. Pounds.
17	Sandy Soil.	Nitrate of Soda. Muriate of Potash. Acid Phosphate.	2.97	3.39
18	Garden Soil.		2.34	3.73
19	Humus Soil.		2.61	3.52
20	Silt Loam Subsoil.		2.47	2.73

SECTION VI.

Plat No.	Kind of soil.	Manures.	Weight of roots. Pounds.	Weight of tops. Pounds.
21	Garden Soil.	Dried Blood. Muriate of Potash. Acid Phosphate.	3.08	3.92
22	Humus Soil.		3.67	2.00

SECTION VII.

Plat No.	Kind of soil.	Manures.	Weight of roots. Pounds.	Weight of tops. Pounds.
23	Garden Soil.	Sulfate of Ammonia. Muriate of Potash. Acid Phosphate.	3.54	4.22
24	Humus Soil.		1.20	1.91

SECTION VIII.

Plat No.	Kind of soil.	Manures.	Weight of roots. Pounds.	Weight of tops. Pounds.
25	Garden Soil.	Stable Manure.	3.92	5.32
26	Humus Soil.		1.28	5.36

SECTION IX.

Plat No.	Kind of soil.	Manures.	Weight of roots. Pounds.	Weight of tops. Pounds.
27	Garden Soil.	Ashes.	2.73	4.30
28	Humus Soil.		0.98	2.06

SECTION X.

Plat No.	Kind of soil.	Manures.	Weight of roots. Pounds.	Weight of tops. Pounds.
29	Sandy Soil.	Nitrate of Soda.	2.95	4.95
30	Garden Soil.	Muriate of Potash.	3.02	5.30
31	Humus Soil.	Acid Phosphate.	2.52	4.50
32	Silt Loam Subsoil.	Lime.	2.25	6.72

SECTION XI.—Kept very wet.

Plat No.	Kind of soil.	Manures.	Weight of roots. Pounds.	Weight of tops. Pounds.
33	Sandy Soil.	Nitrate of Soda.	2.75	5.45
34	Garden Soil.	Muriate of Potash.	2.52	7.19
35	Humus Soil.	Acid Phosphate.	3.13	5.81
36	Silt Loam Subsoil.	Lime.	3.77	4.84

The first thing of interest is the variation between the four plats of section 1. This being the check plat, no fertilizers of any kind were added to the original soil. The garden soil produced the best results both in weight of roots and tops. Figs. 8, 9, 10, and 11 show the characteristic growth in the four soils. The turnips grown in humus soil were far inferior to the others, especially in weight of roots.

The next variation of especial interest is the increased yield in plat 7 over that in plat 3. Both plats had a humous soil, but to that in plat 7 lime had been added at the rate of 1 ton per acre. Fig. No. 12 shows the marked increase in size of roots due to this application of lime. The gain amounted to nearly 50 per cent.

Potash did not seem to give much increase in yield over phosphoric acid; but it was noticed that in section 4, where phosphoric acid and potash were used, the plants tended toward seed production much sooner, and to a greater extent, than in section 3, where nitrogen and potash were used.

It is interesting to note the effect of the source of the nitrogen upon the root growth (see Fig. 13). Below are given the weights of the roots:

Plat No.	Manures.	Weight of roots. Pounds.
18.	Nitrate of soda	2.33
21.	Dried blood	3.08
23.	Sulfate of ammonia	3.55

In the above plats garden soil was used, and the results are greatly in favor of ammonium sulfate as a source of nitrogen. The nitrate of soda is very soluble and quickly available, and some of it may have been washed away and wasted before it could be taken up by the plant, or it may have undergone denitrification and the nitrogen may have been partly driven into the air as gas. Fig. 14 shows the increased yield of roots when garden soil was used in comparison with humous soil. Both soils were treated with stable manure at the rate of 10 cords per acre:

	Pounds.
Yield in garden soil	3.92
Yield in humus soil	1.28

The increased yield due to the use of stable manure as compared with ashes was very marked, and is illustrated in Fig. 15:

	Pounds.
Yield with stable manure	3.92
Yield with ashes	2.73

As has been said before, the main object of the experiment was to determine, if possible, the effect of moisture on the root growth. Sections 10 and 11 were treated especially with that point in view. Each one received the same application of chemical manures, with lime. Section 11 was kept quite wet, while section 10 received normal waterings. The results were distinct and quite uniform in all four soils. It was found that in the wet soil the fine roots were more numerous and that they covered over two-thirds of the area of the turnip, coming nearer the surface. The larger tap-roots were also more numerous and shorter, and instead of coming from the bottom, or near the bottom, of the turnip, they also grew from the

side. This necessitated a large amount of trimming, which greatly injures the market value and the keeping qualities of the product. It was also found that those turnips grown on the wet soil were more scabby than the others, some being so badly scabbed as to be useless for market purposes. On the other hand the turnips grown under normal moisture conditions were smooth, and comparatively free from scab. These had less small roots and the large ones came from nearer the bottom, thus leaving a greater area of sound perfect root after trimming. From these results we see that the turnip does best on a moderately dry soil. Figs. 16 and 17 show this variation in roots due to excess of moisture. Those on the right were grown on very wet soil, and those on the left on normal soil.

The following summary shows the most important facts learned:

1. The turnip grows best on a garden soil which is sandy rather than silty or clayey.

2. Lime was not beneficial in this particular instance when applied alone except on the humous soil. Lime is nevertheless helpful on many ordinary soils, at least under field conditions; yet it should only rarely be used without other manures.

3. The application of chemical manures increased the growth of the tops more than the growth of the roots.

4. Potash was the manurial ingredient which was the most advantageous, and when combined with phosphoric acid better yields resulted than with any other combination of chemical manures.

5. Nitrogen was apparently not needed to any great extent. A slight increase in yield was noticed when it was applied in sulfate of ammonia, but when applied in nitrate of soda or dried blood no beneficial results were obtained.

6. Stable manure gave an excellent yield, both in tops and bottoms; but scab was more prevalent than where chemical fertilizers were used.

7. Ashes showed no increase in root growth over the check plat, but they increased the growth of tops about 50 per cent.

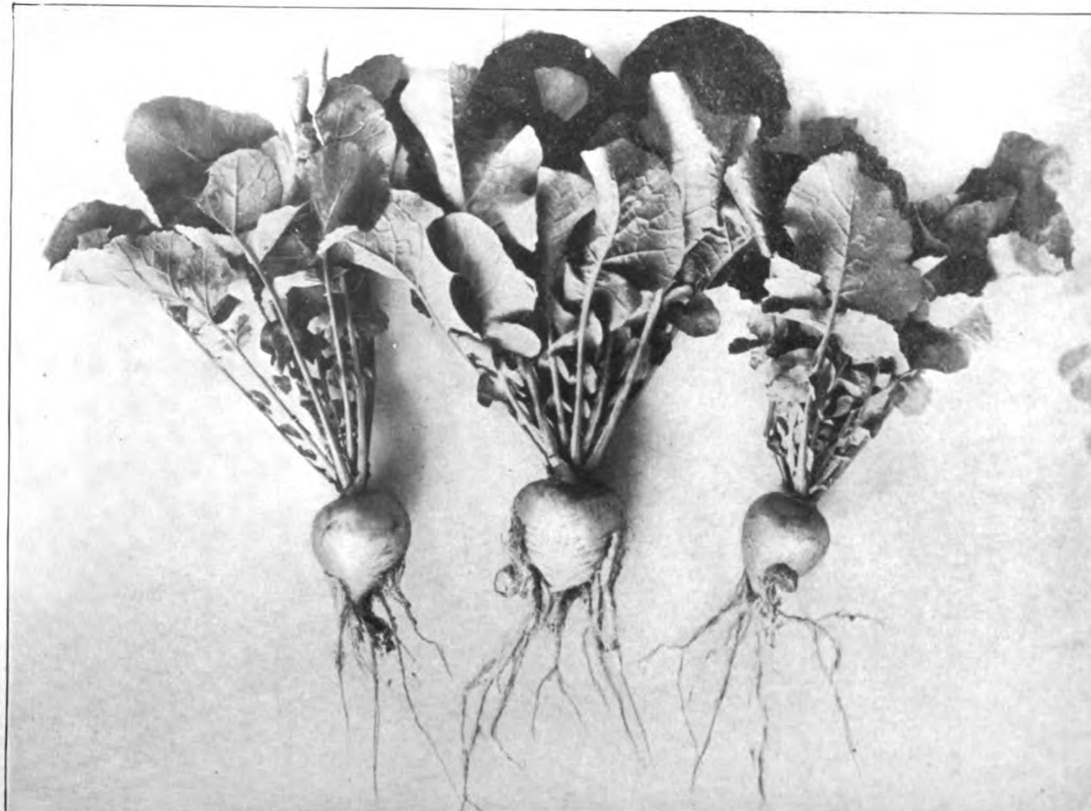


Fig. 8.—Sandy Soil, Without Fertilizer.

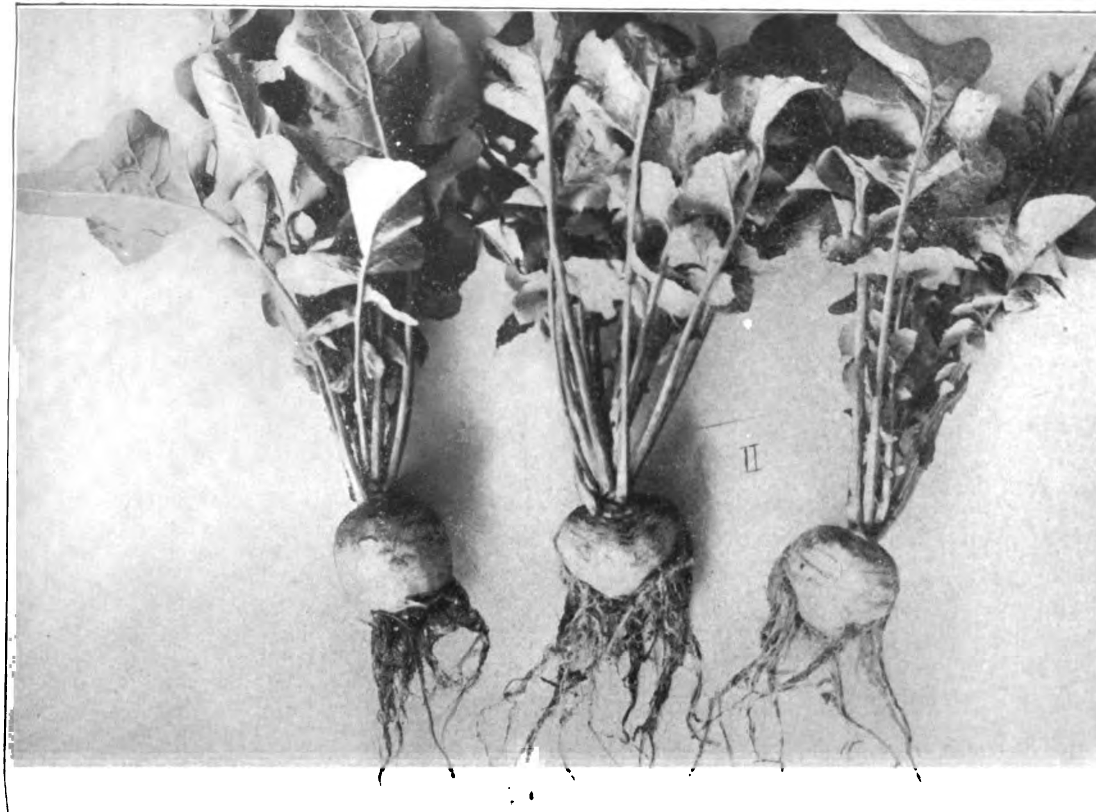


FIG 9.—GARDEN SOIL, WITHOUT FERTILIZER.

Fig. 10.—Humus Soil, Without Fertilizer.

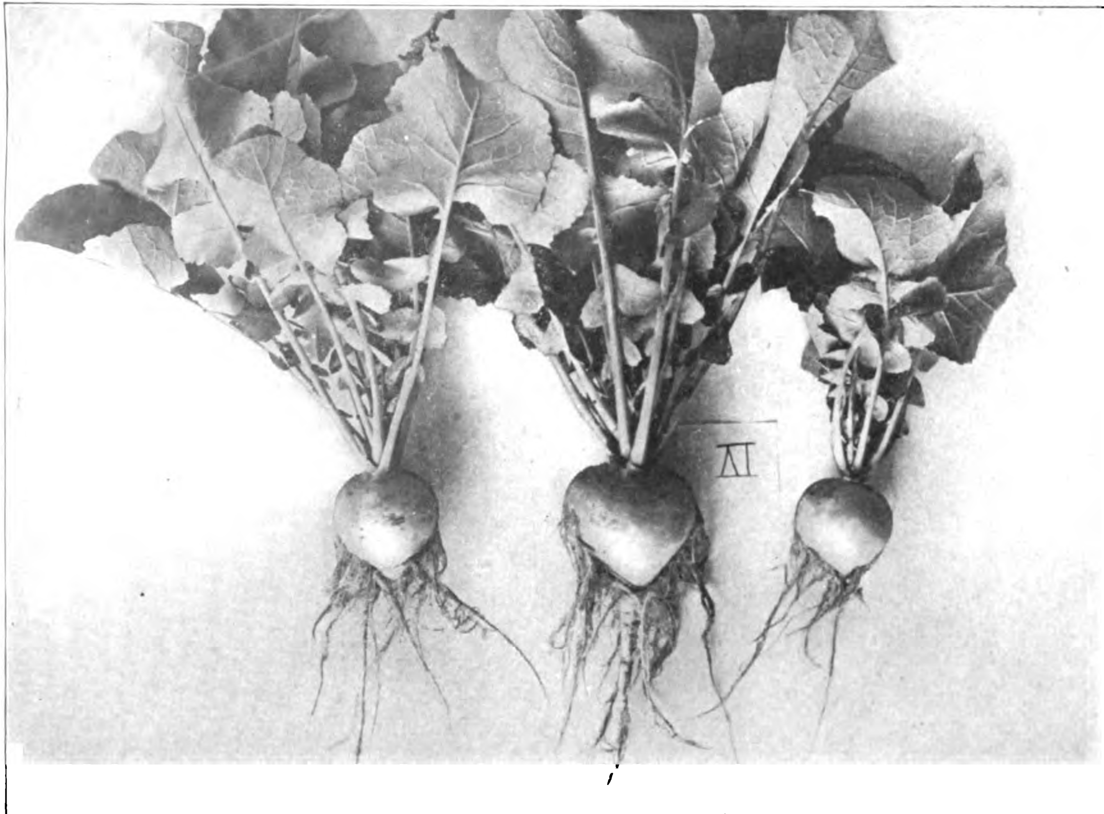
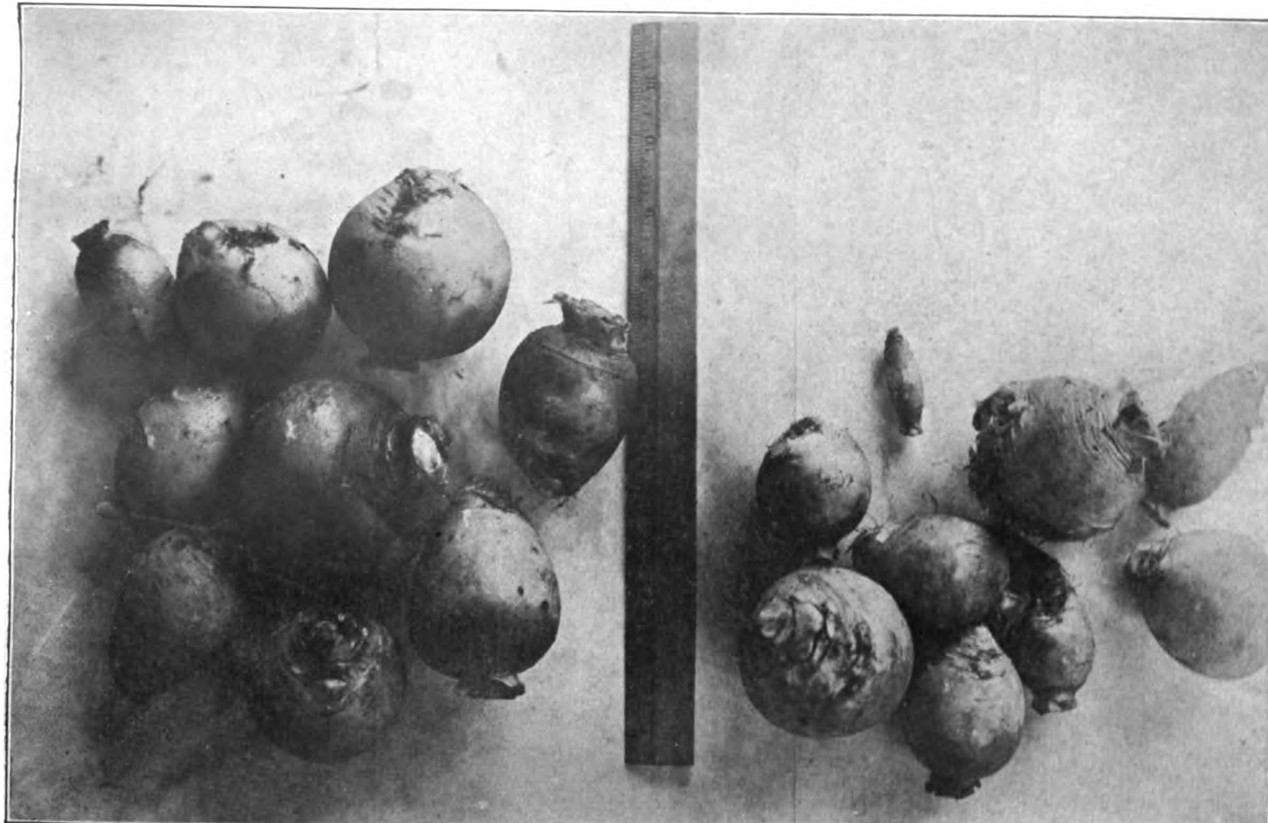


Fig. 11.—Clay Soil, Without Fertilizer.



Limed. Unlimed.

FIG. 12.—HUMUS SOIL, WITHOUT FERTILIZER.

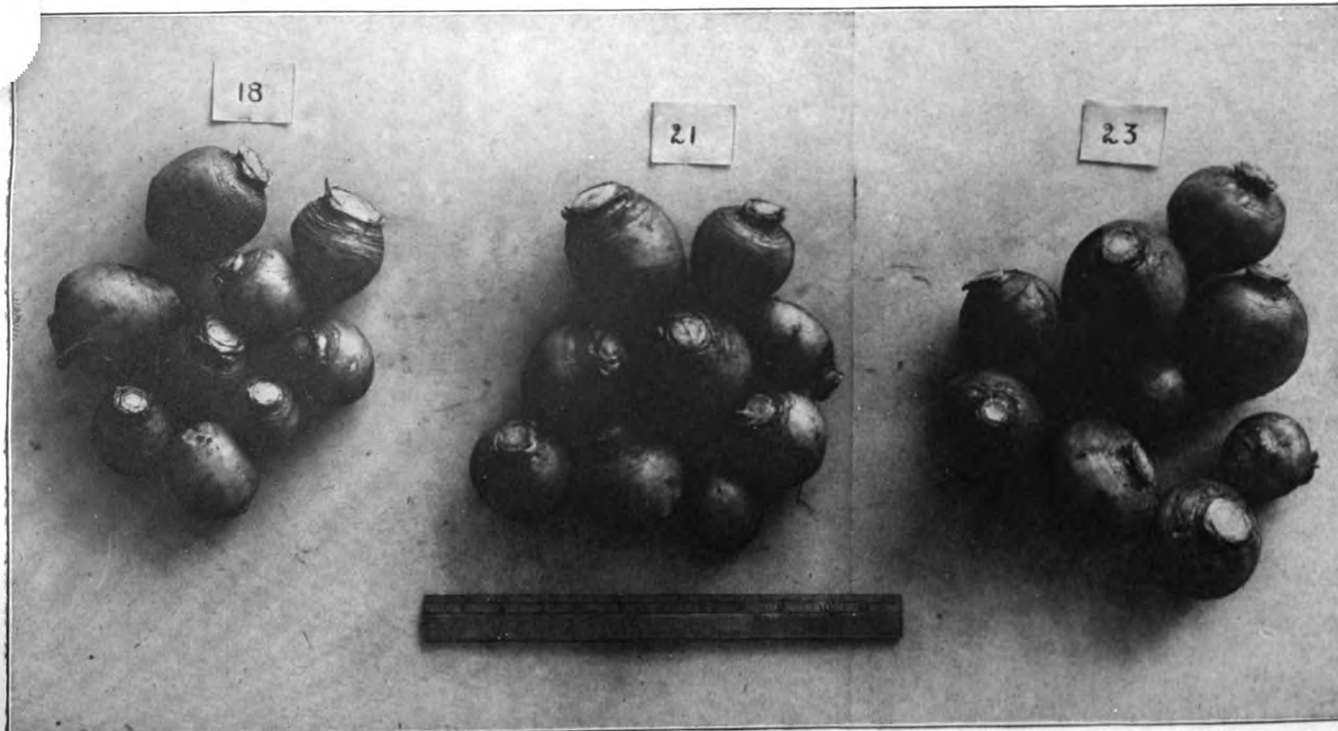


Fig. 13.—Garden Soil.

Nitrate of Soda. Dried Blood. Sulfate of Ammonia.

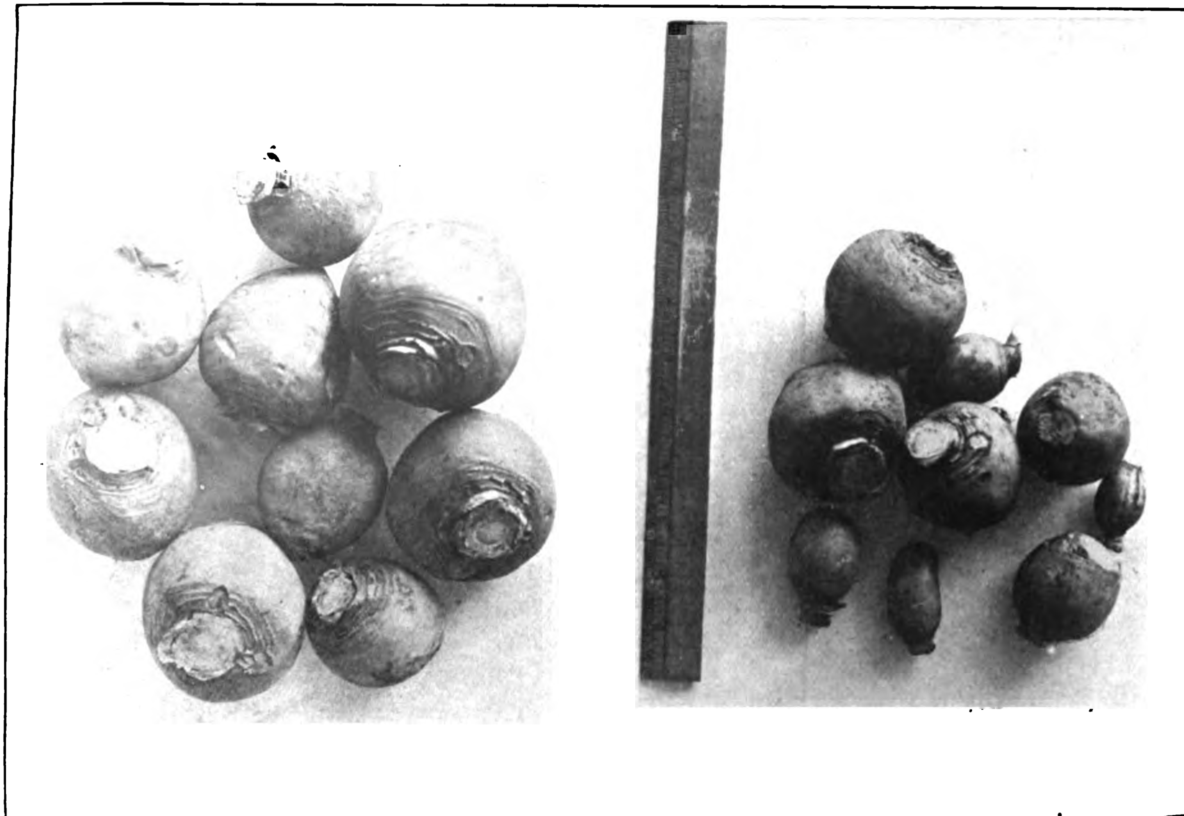
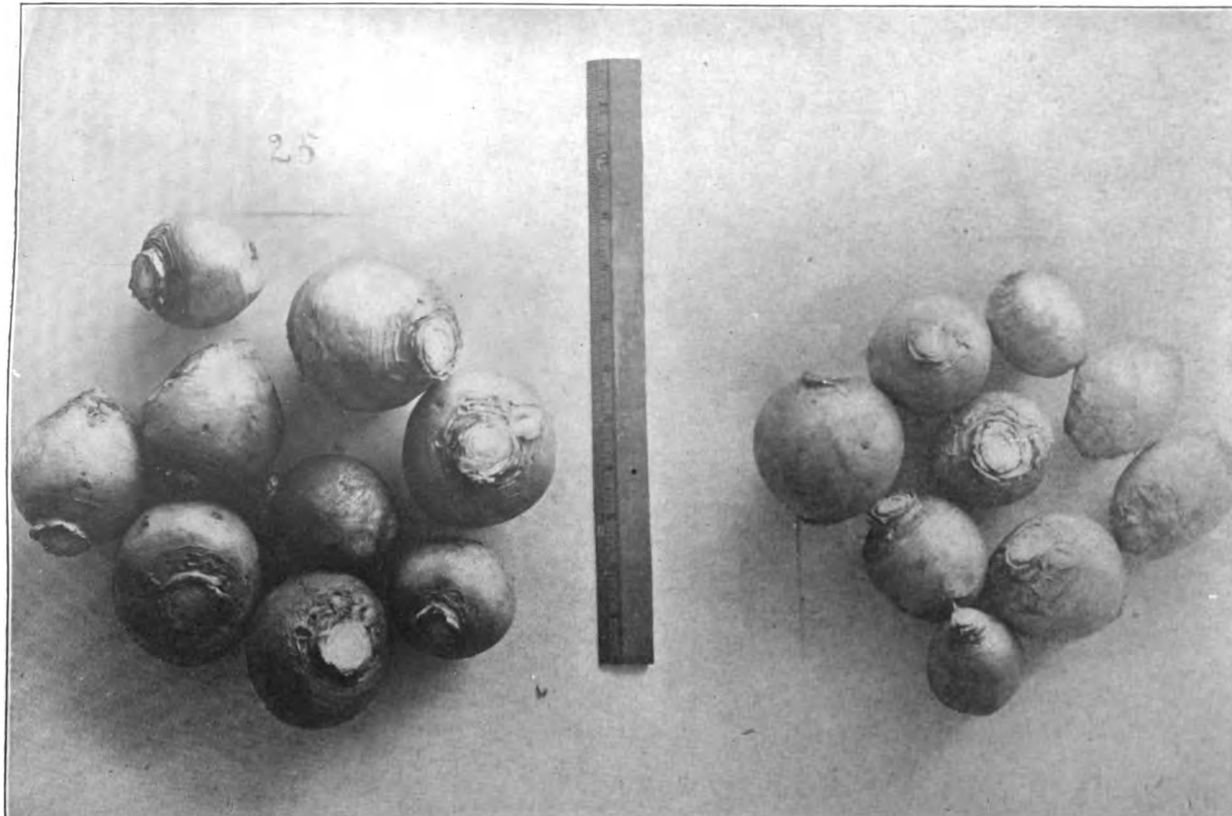


FIG. 14.—STABLE MANURE.

Garden Soil — Humus Soil.



Stable Manure. FIG. 15.—GARDEN SOIL. Wood Ashes.

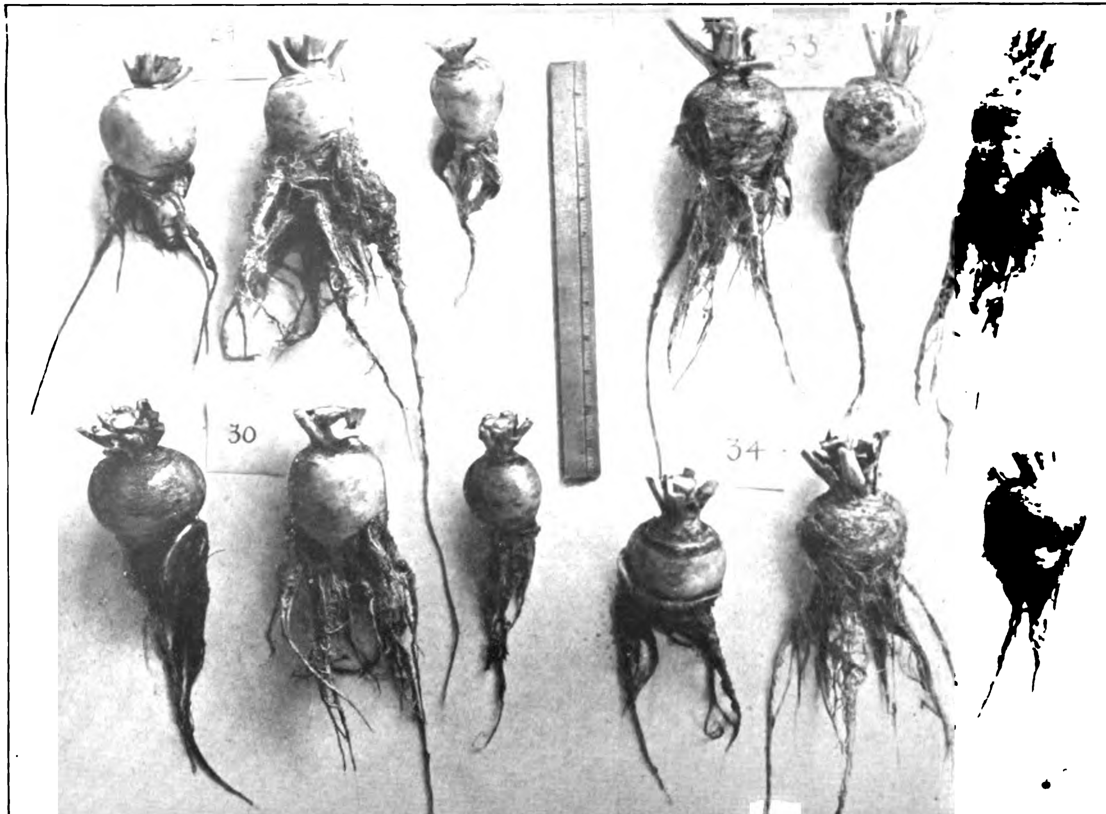


Fig. 16.—Effect of Excessive Moisture.

Dry.
Sandy Soil, 29 and 33

Wet.
Garden Soil 30 and 34

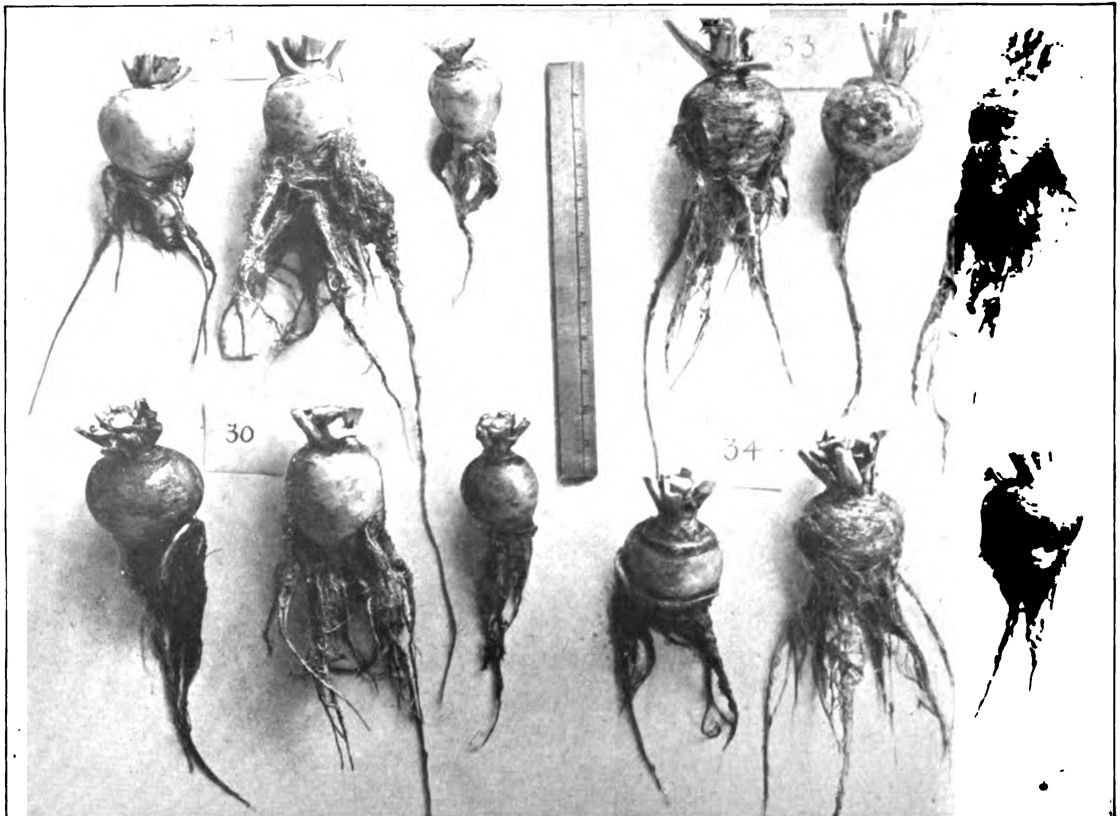


Fig. 16.—Effect of Excessive Moisture.

Dry.
Sandy Soil, 29 and 33

Wet.
Garden Soil 30 and 34

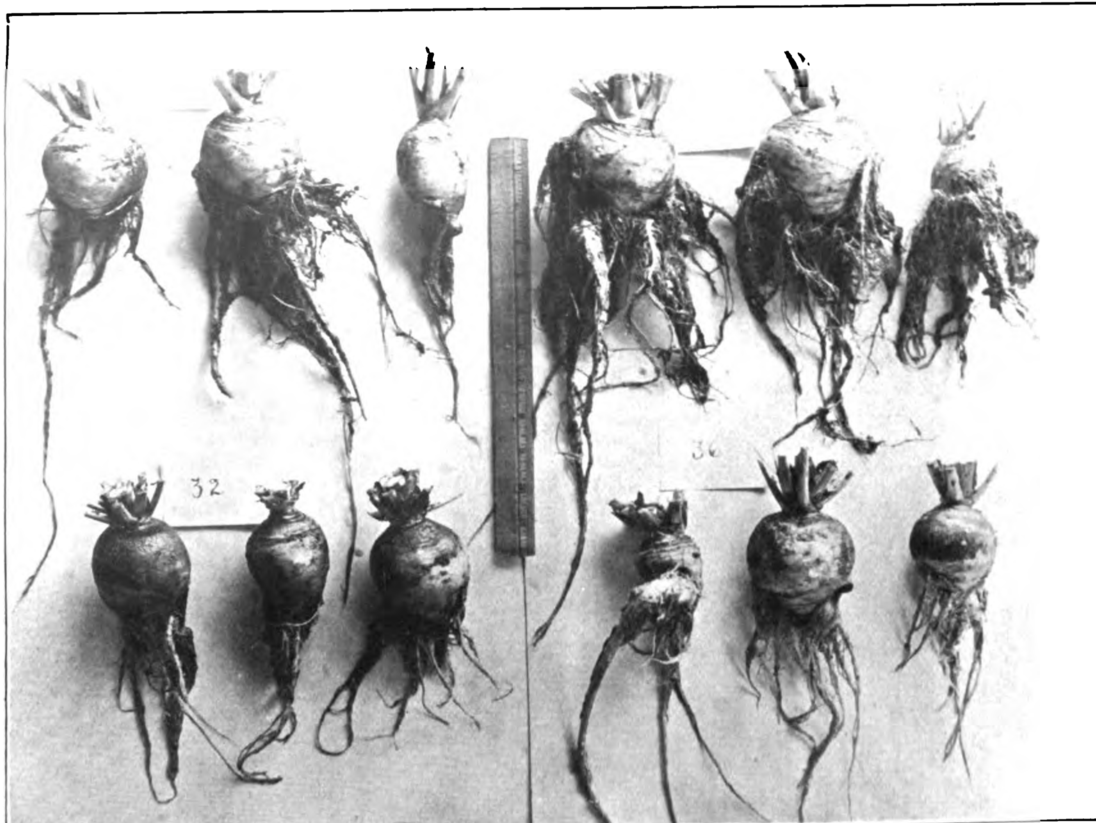


FIG. 17 —EFFECT OF EXCESSIVE MOISTURE.

Dry. Humus Soil, 31 and 35.

Wet. Clay Soil, 32 and 36.

8. Turnips did better on a moderately dry soil than on a very wet one.

9. Lime was beneficial when applied with the chemical manures.

WINTER TEMPERATURES.

The effect of altitude and consequent air drainage upon temperature is often an important matter in fruit growing or in the growing of tender ornamental plants. In order to observe how great the differences are under different conditions, Mr. A. E. Wilkinson, a senior student in 1906, was asked to make records of the temperatures at different places for a period of time during the coldest weather of winter. The records began January 17 and closed March 21, 1905. Six minimum recording thermometers were numbered and placed as follows:

No. 1, on the rail at the top of the windmill. This windmill stands on nearly the highest ground of the College farm. The thermometer at the top of it was therefore higher and much more exposed than any of the others. At times the jar of the windmill caused the indicator in this thermometer to drop so that readings could not be taken. This will explain the blanks seen in that column.

No. 2 was placed on a peach tree in the College orchard. This tree was located north of the road leading to the mechanical building, and represents land well toward the top of the slope.

No. 3 was placed on an oak tree west of the gunpowder house. This was slightly lower than the one on the peach tree, and it was somewhat protected from cold winds by woodland on the north.

No. 4 was placed on a telephone pole south of the pump-house on the plains. This represents the average altitude of the plain land.

No. 5 was placed on an old building which stood temporarily southeast of the football field. This was still lower than No. 4, being in the lowest part of the valley.

No. 6 was placed on the beehouse near the stone quarry. This

location is closely surrounded by a planting of pine trees, and is therefore well protected from the wind.

In all cases the thermometers were placed on the north side of the object to which they were attached.

The following record shows the minimum temperature for each twenty-four hours, and also the temperature at 10:30 A. M. and 4:30 P. M. each day:

No. of thermometer.	Minimum. 1	2	3	4	5	6	10:30 A. M. 1	2	3	4	5	6	4:30 P. M. 1	2	3	4	5	6	Weather.
Date.																			
Jan. 17	....	12	12	..	8½	11	26	26	27	..	28	28	32	27	28	29	26	28	....
Jan. 18	13	11	13	12	9	12	22	20	23	26	24	24	34	30	30	30	28	30	....
Jan. 19	22	20	20	19	14	19	41	37	39	41	38	39	40	38	37	38	35	37	....
Jan. 20	26	24	25	20	17	22	35	33	34	33	28	29	38	40	37	37	35	36	....
Jan. 21	....	21	20	19	16	18	34	31	30	29	26	29	33	32	31	30	28	30	....
Jan. 22	27	22	17	13	11	18	38	35	36	33	30	34	35	34	34	32	35	34	....
Jan. 23	15	14	10	12	9	13	23	21	18	19	16	20	21	19	18	18	16	18	....
Jan. 24	8	7	6	6	3	6	12	10	9	9	6	8	26	25	24	25	22	24	....
Jan. 25	12	11	11	11	9	10	14	13	12	12	11	11	10	8	9	8	6	9	....
Jan. 26	5	4	4	5	3	3	7	6	7	7	5	5	13	12	12	14	11	12	....
Jan. 27	7	5	5	4	—1	2	15	13	12	12	11	13	26	23	24	24	22	23	....
Jan. 28	14	13	13	9	6	11	29	27	28	30	28	28	27	26	27	27	24	26	....
Jan. 29	13	6	7	5	2½	3½	22	24	23	25	21	22	24	26	25	28	24	24	....
Jan. 30	....	10	10½	8	3	5½	17	18	18	20	20	21	20	20	20	21	19	19½	....
Jan. 31	10	8	9	9	6	6	18	19	19	19	20	20	20½	21	21½	22½	22	21	....
Feb. 1	4	4	3	—2	—6	—2	21	24	22	27	26	23	24	25	24	25	25	24	....
Feb. 2	19	18	17	16	13	15	22	21	21	21	20	21	16	18	17	18	17	17	....
Feb. 3	4	2	2	2	1	1	10	11	12	12	12	10	16	17	17	18	16	17	....
Feb. 4	—2	—3	—4	—6½	—8	—7	11	13	12	13	13½	12	13	12	12	12	11	12	....
Feb. 5	—2	—3	—4	—4	—7	—3	17	20	18	18	18	17	23	24	24	24	23	24	....
Feb. 6	16	16	16	13	12	13	28	28	28	27½	29½	27	31	30	30	30	29	30	....
Feb. 7	....	18	17	19	18	17	22	21	21	22½	22	20	19	20	19	19½	19	18	Calm.
Feb. 8	7½	9½	9½	9	8	7½	17½	18	18	17½	18	14	29	29½	28½	28	27½	26½	Calm.

No. of thermometer..	Minimum. 1	2	3	4	5	6	10:30 A. M. 1	2	3	4	5	6	4:30 P. M. 1	2	3	4	5	6	Weather.
Date.																			
Feb. 9	26	20	17	9½	9	12	35	34	34	33	32	32	31	30	30	31½	31	30½	Snowing.
Feb. 10	....	23	30	29	26	27	34	34	35	33	32	35	30	32	31	30	30½	29	Rain and freezing.
Feb. 11	....	15	15	17	17	15	15	17	18	18	19	16	22	23	22	22	21	20	Raw.
Feb. 12	....	5	5	—1	—2	—1	17	19	18	16	19	17	30	29	29	31	28	30	Calm.
Feb. 13	30	28	28	29	26	29	34	34	33	34	32	33	26	24	24	22½	22½	22	Rain.
Feb. 14	4	3½	3½	4½	4	2½	12	10	11	11½	12	9½	15	15	15½	15	13	14	Calm.
Feb. 15	7	4	5	3	2	3	21	20	21	18½	19½	13	28	27	28	27	26	28	Calm.
Feb. 16	4½	4	4	5	5	3	10	10½	10	10½	11	10	17	18	17½	17½	17	16	Windy.
Feb. 17	11	12	11½	13½	11	11	32	33	33	32	31	33	34½	34	34	35	34½	34	Calm.
Feb. 18	18	17	17½	19	17	17	21	21½	21	22	23	20	20	20½	20	21½	21	20	Windy.
Feb. 19	5	4½	5	2½	0	1	18	19	19½	20	20	18	17	19	18	19	18	19	Clear.
Feb. 20	14	14½	14	10½	9	11	31	30	34	34½	34½	32	35	34½	34½	34	34	35	Clear.
Feb. 21	25	28	27½	26	24½	24½	40½	39	41	40	39	40	34	34	34	35	32	33	Clear.
Feb. 22	....	24	25	25½	25	24	25	29	30	30	31	29	23	22½	23	22	21	22½	Clear.
Feb. 23	....	18	18½	19	19½	18	21½	21	22	21½	21	21	30	30½	31½	31½	30½	30	Windy.
Feb. 24	21½	19	20	21	19	18	31	31½	32	31½	31	30	38½	38	37½	38	38	37	Windy.
Feb. 25	....	16½	17	15	12	16	32½	33	33½	33	32	31	38	37	37½	37½	37	38	Clear.
Feb. 26	26	23	21	18	14½	16	36	35	35½	34	38	36	35½	35	36	35½	36	36	Calm.
Feb. 27	17	17½	17½	18½	17½	16	22½	23½	23½	24½	24½	23	27½	28	28	27½	27½	27	Windy.
Feb. 28	15½	14	15	10½	8½	12	34	33½	34	34½	34½	31	35½	36	35	34½	34½	34	Windy.
Mar. 1	....	18	18½	19½	18	17½	24	25½	26	25½	27	23	[illegible]	30	30	30	29	28	Clear.
Mar. 2	....	9½	10	8½	7½	8	16	18	18	17½	18½	18	26½	26	26	28½	27	27	Calm.
Mar. 3	13	10½	10	6	4½	7½	30½	30	30	31	29½	29	34	34	36	36	35	34	Calm.

No. of thermometer..	Minimum.						10:30 A. M.						4:30 P. M.						Weather.
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	
Date.																			
Mar. 4..........	32	20	22	20	18	20	41	41	41	43	44	39	33½	34	33½	34	34	34½	Calm.
Mar. 5..........	22	19	20	11	10	9½	23	26½	27	29½	29	22	28½	29	27½	28½	28½	28	Calm.
Mar. 6..........	22	20	19	17½	14½	17	29½	32	30½	31½	30½	30	33	34	33½	34	33½	34	Windy.
Mar. 7..........	25	17	16	15½	14½	15	32½	34	36½	36½	35	34	32	32	32	33	32½	31½	Calm.
Mar. 8..........	31	30½	30	31	31	29½	34	34	33½	35	34½	33	35½	36	35½	36	35½	35	Calm.
Mar. 9..........	29½	28½	28½	27½	25	27	42	42	42	42½	41½	41½	36	36	36	38	38	36	Calm.
Mar. 10..........	35	31	31	32	31½	30½	45	45	45	45	45	44½	47	46	46	44½	43½	43	Calm.
Mar. 11..........	21½	22	21	21½	21	20½	32	31½	32	31½	31	30½	29	27½	28	27	27½	27	Windy.
Mar. 12..........	....	19	19½	17½	15	16	34	34	36	37	38	35	35	35½	35	35	34½	34½	Calm.
Mar. 13..........	....	18	16½	18	16½	15½	27½	28	28	27½	27½	27	31½	32	32	32	31½	31	Calm.
Mar. 14..........	....	17	17½	16	13½	15	32½	33	32	33	33	33	32½	32	32	33	32	31	Calm.
Mar. 15..........	17	17	16½	17	14½	15½	29	29	29½	29	27½	29	32	34	36	35	34	35½	Calm.
Mar. 16..........	25½	25	25	18½	15	18	33½	34	33½	34½	34½	32	35	35½	35	36½	36	36	Calm.
Mar. 17..........	25	25½	25	25½	25	24½	41½	42	42	42	41½	40½	39½	42	41½	42	41	41½	Calm.
Mar. 18..........	29	25	25	23½	22	24½	49	47½	48	47½	45½	44	51	51½	51	51	50	50½	Calm.
Mar. 19..........	41½	40	39½	38	36	37½	47	46½	47	47	46	45½	48½	48	47½	48½	48	46½	Calm.
Mar. 20..........	31½	32	32	32	31½	31½	31½	32	32	32	31½	31½	29½	30	30½	30½	30	30	Calm.
Mar. 21..........	31½	31½	31	31	30	29½	34	33½	34	34	33	32½	29½	30	30½	32	31½	30½	Calm.

Division of Animal Breeding and Pathology.

FIG. 1.—View of the entrance to the poultry plant showing incubator house with hothouse attached, brooder house and brooder-house runs, storehouse, and roof of workshop.

REPORT OF THE DIVISION OF ANIMAL BREEDING AND PATHOLOGY.

LEON J. COLE.

The Division of Animal Breeding and Pathology was created to continue the work which previously had been carried on by Doctor Curtice upon the disease commonly known as "blackhead" in turkeys, and, in addition to undertake certain other investigations, mainly along the line of breeding, as the name of the division indicates. For the time, however, it has seemed advisable to devote most of the energies of the division to the study of the disease mentioned, together with such subsidiary work in breeding as had a bearing upon the same problem. The pathological side of the question has involved a study of the lesions, or morbid anatomical changes, produced by the "blackhead" organism, an attempt to follow the life-cycle of this organism, and to determine the means by which it may be transmitted, as well as a search for means for its prevention or cure. The work in breeding, as related to the study of this disease, consists in an attempt to obtain a strain of turkeys which shall be highly resistant or immune to its ravages. In this connection have to be considered the possibility of obtaining such a strain by the continued selection of birds which evince a greater degree of resistance, by the preserving and perpetuating of such individuals as may show a marked natural immunity, or by the introduction and infusion of wild blood, in this way possibly increasing the vitality and resistance of the race.

An endeavor was made at the beginning of the year to segregate,

more than they had previously been, the buildings and other property of the College and Experiment Station poultry plants. Such a division seemed desirable because of the different functions of the two departments, and of the distinct lines of work which they were carrying on, the one mostly instructional, the other experimental. As a result, an agreement was reached by which there was set aside for the Experiment Station a definite tract of land upon which its buildings and yards, should be located. All buildings belonging to the College poultry plant, which chanced to be on this area, were either acquired by exchange or were removed. In addition to the buildings which were on the grounds as a result of these transactions, a well-built house which had formerly served as an apiary was moved up from the woods on the hillside and converted into a storage house for grain. On account of its good construction it was admirably adapted to this purpose. Another larger building belonging to the Experiment Station, which was, however, in such bad condition that it was with difficulty held together, was moved up from the plains. This was repaired at comparatively little expense, and made into a good building for general storage purposes. The accompanying plan shows the location and arrangement of the buildings and yards as they are on July 1, 1907.

In conducting experiments in breeding it is necessary that the pedigree of any individual should be accurately known and readily accessible. As fowls are ordinarily mated in pens, one male to a number of females, this is not the case unless the females are trapnested. So far as could be learned, this method had never been attempted with turkeys, and persons familiar with the methods of turkey-growing, who were consulted, were of the opinion that the trapnest could not be used successfully with these birds. The plan was accordingly adopted of dividing the yards by temporary fencing into a number (usually five) of smaller pens running lengthwise of the larger yard. They were stopped short of the front fence of the yard, however, so that a cross partition here made a pen across the front of the yard, from which all the other small pens could be entered.

This arrangement will be readily understood by consulting the plan referred to above. During the breeding season a hen turkey could now be put into each of the longitudinal pens, while the tom which it was desired to mate to them, could be kept in the pen running along the front, and could be turned in successively with the different hens.

The above method of keeping the matings straight was adopted in most cases, but in three yards it was decided not to make the subdivisions, but to allow the hens to run together and to attempt to identify the eggs by trapnesting the laying hens. Three trapnests were accordingly constructed, slight modifications of the same principles ordinarily used in the trapnests for fowls being employed. They were, of course, considerably larger than those used for fowls, but in other respects were much the same. One of these was placed in each of the yards mentioned. They were used throughout the laying period with complete success, the turkey hens taking to them with great readiness. It should be mentioned, however, that the hens in these yards were thoroughly domesticated, gentle birds, accustomed to confinement in yards. No attempt was made to trapnest the wild or half-wild birds, though it seems not unlikely that under favorable conditions the method might be employed with them as well. In the opinion of some, trapnesting turkeys would make them become broody earlier than would otherwise be the case, but no indication of such a result was seen in the experiments tried.

Of equal importance with keeping the matings straight is the keeping of the records of such matings. It is necessary not only that these records should contain all the essential data, but that they should be as simple as consistent with the end in view, should be readily intelligible to anyone who might have occasion to use them, and should be so arranged that the desired information may be obtained from them with a minimum of labor. A modification of the card system, specially adapted to the needs of the occasion, was finally devised and adopted. By this system the records of both the breeding and pathological work are kept in compact form,

while incidentally much important data on other questions is being accumulated. Furthermore, records are kept of all matings, as well as of all eggs laid and the disposition made of them—whether they are incubated naturally or in an incubator, or by both methods; not only how many, but what ones are fertile, infertile, or die during incubation; and, finally, what ones hatch. At the time of removing the young turkeys from the incubator, each one receives a numbered leg-band, and records of its later history are kept upon cards correspondingly numbered. These cards give all the essential data, such as its parentage, breed, sex, coloration, etc., which are of importance in the breeding work; and, in addition, there is kept upon them a record of the individual's history in relation to disease, especially "blackhead," its weight at various times, and similar information. This record continues throughout its life, noting all the matings made with the bird, and finally, its death, together with the findings of the post mortem examination.

This system, which combines many of the features used by others in similar lines of work, has not yet been in use long enough to have been perfected in all its details, so that a full description of it at this time does not seem advisable. It has, however, given such satisfaction for the period that it has been in use, that it may seem desirable at some future date to present a complete and detailed account of the methods for the benefit of other workers.

In addition to the plans for work in breeding already mentioned above, which were to attempt by this means to secure a breed of turkeys immune or highly resistant to the "blackhead" disease, experiments are also being conducted which bear upon problems of a broader nature. It would seem that the greatest advance in practical breeding is to be made by gaining knowledge as to the fundamental principles of inheritance, which must be the basis underlying all scientific work in the breeding of animals and plants. The empirical methods which have been in use by breeders for hundreds of years have apparently reached their limits, as far as any real advance is concerned. A more complete knowledge of the

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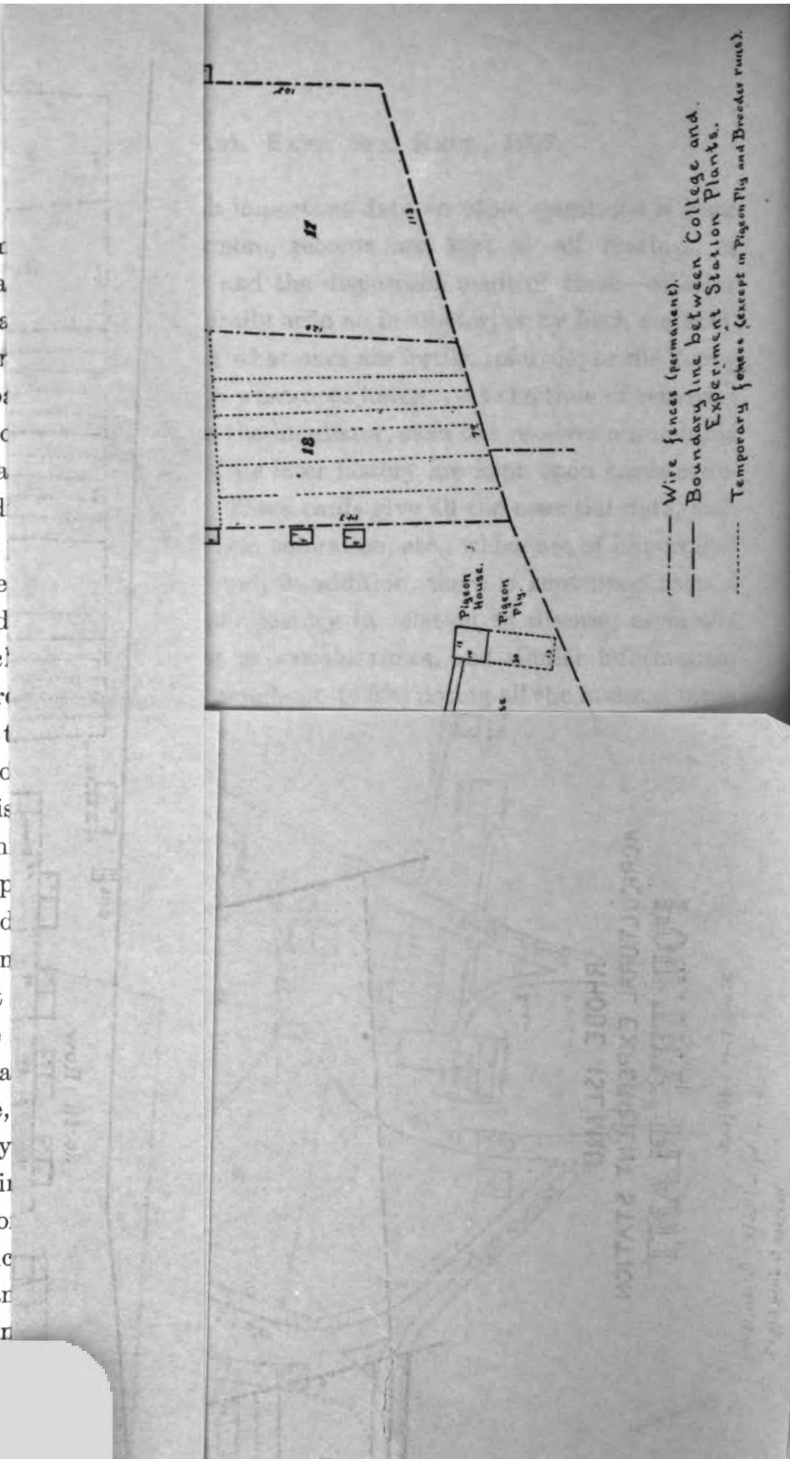

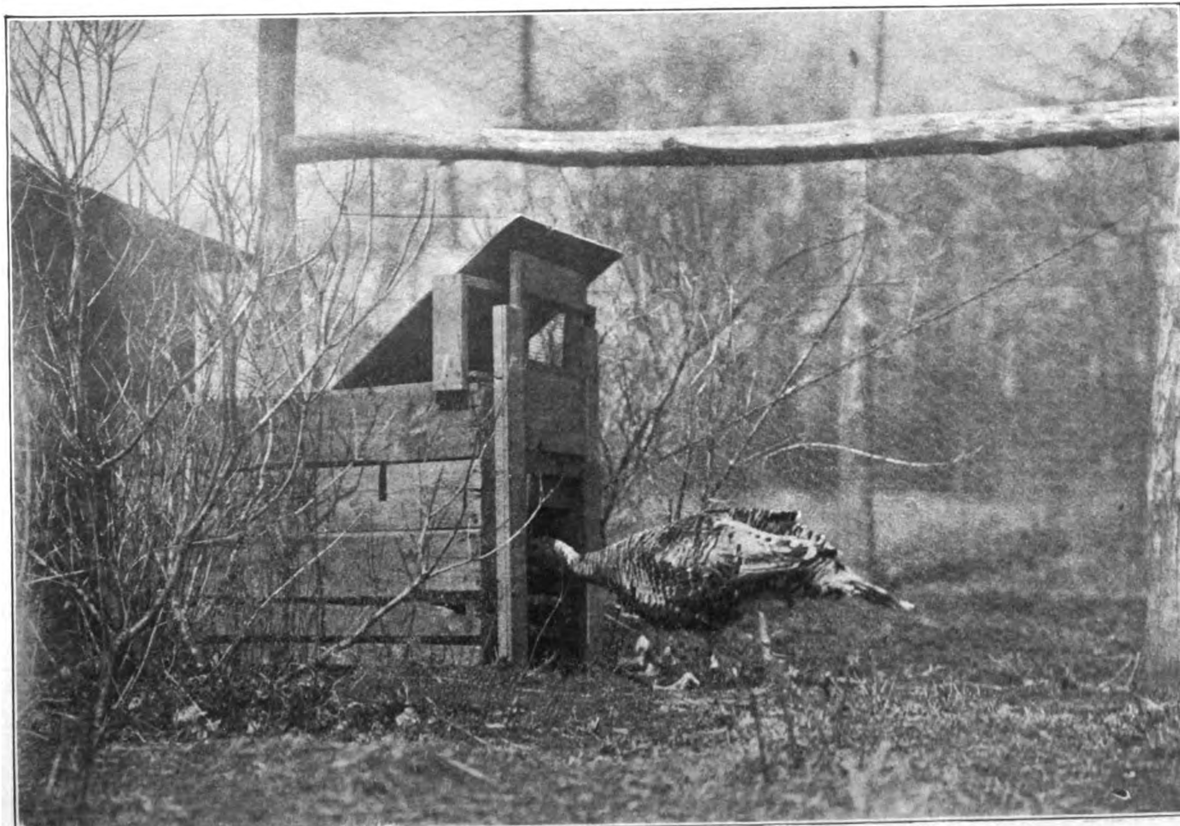

Fig 2.—Turkey Hen entering trap nest.

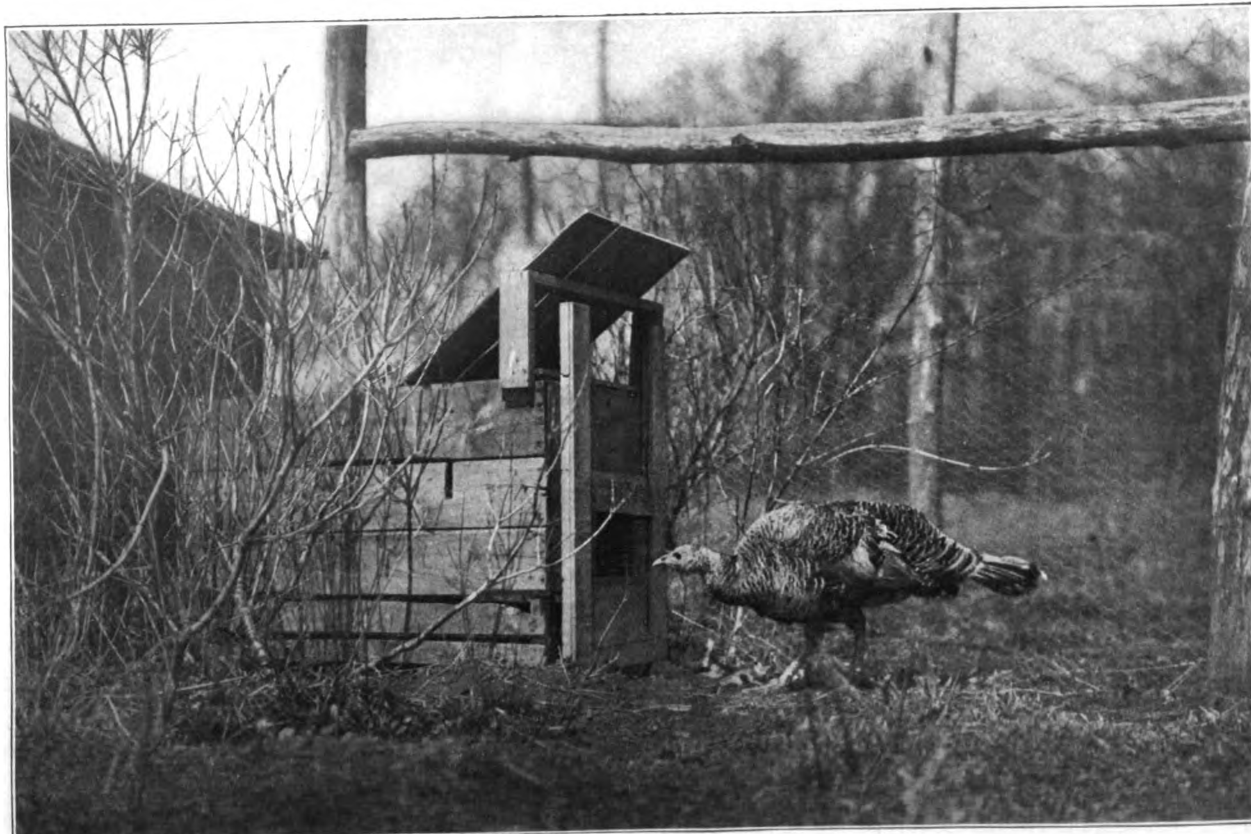

Fig. 3.—Turkey Hen attempting to get into trap nest after one turkey has already entered and door has dropped.

principles of inheritance may or may not permit us to accomplish results which we have heretofore been unable to obtain, but certain it is that it will furnish us short cuts and certain paths to the goal which has formerly been reached only by long and laborious, and usually most uncertain, efforts. It is apparently only by the study of averages obtained from large amounts of data that these general conclusions are to be reached, a method which was first fully appreciated by Gregor Mendel, whose work laid the foundations of what are now generally spoken of as the Mendelian Laws of Inheritance. The essential feature of these laws, and those which have grown out of them, is that they are established on a mathematical basis. In collecting data for the establishment of such laws it is necessary that large numbers be dealt with, and that the records of all the off-spring be taken into account. Now, from what has gone before, it will readily be seen that turkeys under present conditions, do not furnish the most favorable material for the gathering of this kind of data, for the reason that such a large proportion of the off-spring die before reaching an age at which they develop the characters that are being studied. It is hoped, however, that by the keeping of careful records, much may be learned of the inheritance of some of the more prominent characters, such as those, for example, that distinguish the different breeds.

In the furtherance of this work, and for the purposes of demonstration, an attempt has been made to have at the Station a few good representatives of each of the recognized breeds of turkeys. Owing to the limits in price which it seemed advisable to pay, and to the devastations by "blackhead," there are, however, some gaps still to be filled.

On account of the difficulties of obtaining all the desired data with turkeys, it was decided advisable to do some supplemental work along this line upon other birds. For this pigeons were chosen, because of the frequency with which they produce young, their comparative inexpensiveness and ease of management, and because it was believed that results obtained upon these birds might be

applied to poultry in general. At present a study is being made principally of the inheritance of colors in the pigeons, and for this purpose birds all of one breed were chosen. The requirements seemed to be met best by the Tumblers, birds of good color being readily obtainable in this breed.

With regard to the progress in the study of "blackhead" during the year, it must be remembered that the experimental work upon this disease can be carried on to advantage only during the season when there are young turkeys for use in the experiments. Most of the work during the year was, therefore, preparatory to this summer's investigations. Up to the close of the year a large number of poults had been hatched, but only one, which was exposed before the others, had died of "blackhead."

Nearly all of the young turkeys hatched in 1906 had been placed by Doctor Curtice in pens a half-mile or so from the poultry plant, upon land known as "the plains." This was for the purpose of raising them upon ground where there was less danger of infection with "blackhead" than in the regular yards, and the attempt to raise the birds in this way was in such large measure successful, that in the fall there was a fine flock of young stock at the plains. Some of this was marketed, and thirty birds were turned over to the Division of Animal Feeding for experimental purposes. It then became a problem whether to bring the remainder of the birds, which was desired as breeding stock for the coming year, to the central plant, and risk exposing them to infection there, or whether to leave them at the plains. As the latter course would have involved considerable expense and no small amount of labor, and as the birds would have to be brought up to the breeding pens at the central plant in any case in the spring, it was finally decided not to wait. This stock was accordingly transferred on December 5. As was to be expected, the "blackhead" soon began its ravages, and many of the young birds died of this disease, which continued endemic throughout the winter. The data from these birds, together with other facts, go to show that whereas the percentage of loss is

probably not quite so great in turkeys which are not exposed to the disease until they are several months old as it is when they are exposed immediately or soon after hatching, nevertheless, they can not be said to become immune to the disease at any age. The lower percentage of deaths may, perhaps, be credited to a greater vitality and a correspondingly greater resistance to the "blackhead" organism in the older birds.

It may be stated at this time, as a point in favor of the theory upheld by Doctor Curtice that the domestic fowl is largely instrumental in the maintenance and dispersal of "blackhead," that there have been examined by this division during the past spring a number of chickens which, to all appearances, have died of this disease. Much evidence is accumulating, in fact, which would seem to indicate that the malady is much more widespread than is commonly supposed. The station constantly maintains at its plant a number of different varieties of fowls for the purpose of ascertaining to what extent they may be susceptible to "blackhead."

In addition to the experimental work being carried on, the division has held itself in readiness at all times to examine into epidemics and miscellaneous diseases of poultry and other animals throughout the State, and to furnish information and advice so far as lay within its power. By far the greater number of inquiries that come in relate to the diseases of poultry.

This report would be incomplete without mention of the ready and efficient service that has been rendered by the assistant and other employees of the division. Mr. Kirkpatrick has rendered intelligent assistance in the overseeing of the field work and many of the experiments, and by the use of judgment and accuracy in keeping his records. Mr. Kolbe's services, as a practical and experienced poultryman, have been invaluable in the management of the stock. It is gratifying to have associated with one, men who are interested in and loyal to their work.

DIVISION OF CHEMISTRY.

REPORT OF THE CHEMICAL DIVISION.

B. L. HARTWELL, ASSOCIATE CHEMIST.

An article in the last annual report concerning the functions of sodium salts, contained a large number of determinations of the ash constituents of various plants grown in soil to which different relative amounts of sodium and potassium, in carbonates and chlorids, had been added. During the past year the study has been extended to the proximate constituents also, of the plants grown under similar circumstances. Sufficiently great variations were found in the amounts of the organic constituents to warrant a continuance of the study, with the crops of the present year. In consideration of the increased yields which result with certain crops when sodium supplements an amount of potassium which is insufficient for their needs, it seems important to ascertain if such a substitution affects unfavorably the organic constituents of the plants. It is hoped that this work will eventually shed some light also upon the physiology of plant nutrition.

The eighteenth annual report of this station contains the results of an attempt to ascertain the amount of available phosphoric acid in soil to which phosphates of different availability had been added during a series of years. Nitric acid of various concentrations was the principal solvent used. Although widely different crop yields were obtained from the several plats, no method was found which extracted amounts of phosphorus from the soil which were indicative of the amounts obtained by the plants. The percentage of phosphoric acid in the dry matter of certain of the crops also failed to vary in the same direction as the crop yields. The flat

turnip, however, proved especially useful in indicating, to a remarkable degree, the effect of a particular phosphate, not only by their yield but by the percentage of phosphorus in their dry matter. Partly to find out if the determination of phosphoric acid in turnips would afford a means for ascertaining the relative deficiency of our soils in phosphoric acid, coöperative soil tests were conducted in a number of different localities in the State in 1906. These tests not only furnished material for analytical work on the above problem, but they were designed to find out the actual needs of the soil, as indicated by the plants themselves, so that the value of the results obtained by the analysis of the plants might thereby be established. Phosphoric acid, and in some cases potassium oxid, determinations were made in flat turnips, Swedish turnips, and table beets from certain of the localities. The results were sufficiently encouraging to warrant a continuation of the work during a second year.

The analyses made in 1906 in carrying out the provisions of the law providing for the inspection of fertilizers, were published in Bulletins 115 and 117. They represent one hundred brands of complete fertilizers, besides about twenty-five samples of wood-ashes, bones, manure salts, etc.

The inspection of commercial feeding-stuffs included the determination of protein and fat in about one hundred and eighty samples. The analyses and discussion of the same were published in Bulletin 119.

The station has coöperated with the Association of Official Agricultural Chemists in testing methods for the gravimetric and volumetric determinations of potassium oxid in fertilizers, for the determination of invert sugar in association with sucrose, of moisture in molasses and massecuites, and of nitrogen and moisture in cottonseed meal and corn meal.

The experiment to ascertain the relative availability of the nitrogen in different materials has been continued in the large pots sunken in the ground. The nitrogen and moisture determinations

in the crops from this experiment have been completed in all of the crops thus far grown, and the publication of the results of the experiment need not be delayed beyond the time when the indications furnished by it may be of interest to the public.

The pot experiment which was begun in 1906, with the object of growing legumes in one of our light, gravelly soils, without the application of nitrogen in so far as possible, has been continued. Soy bean, cow pea, white-podded adzuki bean, and crimson clover, were the first crops planted. Winter vetch, which followed all of these crops during the winter in the greenhouse, was worked into the soil in the spring of 1907, preparatory to planting the four legumes in the same pots as in the preceding year. This experiment includes the analytical work necessary for knowing the net gain or loss of nitrogen whenever the experiment is terminated.

The coöperative soil tests referred to previously, furnished an opportunity for comparing the wire-basket method of the U. S. Bureau of Soils, for determining the manurial needs of land, with results obtained in the field; and the work was undertaken in coöperation with that Bureau. Bulletin 120 includes the data obtained in 1906. The work is being continued by the Station alone, somewhat less extensively, in 1907. Comparisons with the eight-inch Wagner pots have also been included with certain of the soils.

Occasionally, the application of magnesium sulfate to certain of our soils has resulted in a slight benefit, and it has been customary to add a medium amount of this material in certain experiments when it has been desired to preclude the possibility that increases in crop yields, resulting from the addition of some special manurial ingredient, might be due to an indirect action whereby needed magnesium was liberated. Magnesium sulfate has for this reason been added in the field experiment in which the effect of lime has been studied; and the criticism has been made that the benefits derived from liming were due to bringing about a proper balance between calcium and magnesium, which Loew considers so essential for the best growth of plants. In order to add more evidence to

that which had already accumulated at this station, bearing upon this idea, a pot experiment has been conducted in soil from the lime experiment, by which it was shown in a most striking manner that the criticism referred to was entirely wrong. The details of this work will appear at an opportune time.

On account of the renewed interest in ground feldspar as a source of potassium for plants, we were led to try its effectiveness in pots in comparison with sulfate of potash. At least another crop will be grown before the results will be published, but at the present time feldspar is at an economic disadvantage.

In view of the increased yields which have resulted in the field from the addition of sodium when the supply of available potassium was insufficient for the needs of the plant, an experiment in pots was undertaken with soil from certain of the plats with the hope of finding out if the sodium in nitrate of soda and in kainit is economically useful.

It was impossible to state with certainty, by experiments conducted in soil, whether the increased growth due to the application of sodium salts was the result of a direct or of an indirect effect. In coöperation with the U. S. Bureau of Soils, numerous water and sand cultures have been carried on at this station with wheat seedlings, which have shown that, with these seedlings at least, there is a decided increase in growth due to the direct effect of sodium when supplementing a deficient amount of potassium. An account of this coöperative work is given in an article which follows. The Station is continuing the work in solution, when there is opportunity, to ascertain something more concerning the specific effect of sodium salts.

The following miscellaneous analyses have been made during the year either because of their bearing on certain experimental work of the Station or because they are of some general interest. No funds are placed at the disposal of the Station for making analyses which would be of only private interest. The cost of the inspections of fertilizers and feeding stuffs is paid from special funds, and the analyses made in connection with these inspections are published

in bulletins. Certain chemical analyses are not included here because they will be of more interest when published from time to time with the results of experimental work on which they will have an important bearing.

MISCELLANEOUS ANALYSIS.

CALCIUM CYANAMID.

	Per cent.
Nitrogen	19.80
Calcium oxid	59.73

This material is formed in the electric furnace by the combination of atmospheric nitrogen with a mixture of calcium carbonate and coal. It is sometimes called "lime nitrogen," and experiments have shown it to be quite a satisfactory source of nitrogen for plants. It contains a considerable quantity of calcium in excess of the amount required to combine with the nitrogen in the formation of pure calcium cyanamid, and as this calcium is present principally in calcium carbonate, the material is alkaline in its reaction. On account of this fact it should not be mixed with substances, such as sulfate of ammonia and guano, from which ammonia may be easily expelled. The "lime nitrogen" itself gives off ammonia if it becomes moist. Unless it is applied two or three weeks before the seed is planted it is likely to poison the young plants.

"MUCK" OR PEAT.

	Per cent.	
	I	II
Nitrogen in oven-dry muck	2.19	.29

This muck was from a farm in North Providence, near the Smithfield road, owned by Frederick Winsor. It was from a depression occupying an area of about an acre. Sample I was from the surface layer of the deposit and was composed largely of organic matter. Sample II was from the layer below this, which contained a considerable admixture of clayey soil. Sample I compares favor-

ably with the better grades of muck. The amounts of phosphoric acid and potassium oxid in muck are too small to be of much practical importance.

I. Wool and dirt.
II. "Press Cake."

	Per cent. I	Per cent. II
Nitrogen	1.73	1.45

"Press cake" is the material remaining after the removal by pressure, of the fatty substances in wool waste.

I. Sulfate of ammonia.
II and III. Nitrates of soda.

	Per cent. I	Per cent. II	Per cent. III
Nitrogen	21.02	15.88	14.77

I. Finely ground bone.
II. Dissolved bone.
III. Dried blood.

	Per cent. I	Per cent. II	Per cent. III
Nitrogen	2.44	2.25	10.30
Phosphoric acid (P_2O_5)	26.08	*17.34	†2.73

I. Acid phosphate.
II and III. Ignited aluminum phosphate.

	Per cent. I	Per cent. II	Per cent. III
Phosphoric acid	*15.20	45.80	49.55
Aluminum oxid	.....	27.92	29.95
Ferric oxid	.....	3.15	2.36

Ignited aluminum phosphate or roasted redondite has been used at this station several years in comparison with other phosphates.‡

*Mostly in the soluble form.
†Due to an admixture of bone.
‡ See especially Bulletins 114 and 118, (1907).

It is relatively less efficient with soils which are in need of liming than with limed soils, and even with the latter it is considerably less available for most crops than the soluble phosphates. The raw redondite, or unignited aluminum phosphate, is of no practical value as a source of phosphorus.

POTASSIUM NITRATE.

	Per cent.
Moisture	0.32
Potassium oxid	46.44
Nitrogen	13.83

I. MURIATE OF POTASH.
II. "HIGH GRADE" MURIATE OF POTASH.
III. SULFATE OF POTASH.
IV. CARBONATE OF POTASH.

	Per cent.			
	I	II	III	IV
Potassium oxid	49.92	61.87	47.91	57.28

I. COMMON SALT.
II. SODIUM CARBONATE.

	Per cent.	
	I	II
Moisture	1.28	3.88
Sodium oxid	52.40	55.81

CYPHERS'S POULTRY GRIT.

	Per cent.
Calcium oxid	43.57
Magnesium oxid	10.14

This material appears to be magnesian limestone.

MALT SPROUTS.

	Per cent.
Crude protein	24.44

HAY.

From several of the experimental plats, 1906.

Plat No.	Moisture in hay as harvested. Per cent.	Nitrogen.	Per cent. in oven-dry material. Phosphoric acid (P_2O_5).	Potassium oxid.
6	33.49	1.33	.46	2.74
8	29.39	.87	.42	2.19
10	33.92	.91	.40	2.18
28	32.77	.92	.43	2.05
31	25.15	.91	.43	1.99
33	28.07	.91	.43	2.15
77	35.46	1.15	.41	2.36
79	25.93	1.12	.40	2.14
81	36.63	1.15	.42	2.31
83	34.35	1.13	.41	2.15

Analyses of Materials used in a Chicken-Feeding Experiment.

	Moisture.	Ash.	Fiber.	Fat.	Protein.	Nitrogen-free extract.	Phosphoric acid.	Calcium oxid.
Corn meal	11.73	1.36	1.70	3.78	9.00	72.43	.65	.09
Gluten feed	8.90	2.80	6.95	2.89	25.40	53.06	1.06	.30
Wheat middlings	11.48	5.08	7.94	4.59	16.63	54.28	1.09	.14
Oat meal	8.52	1.78	1.08	6.59	14.44	67.59	.91	.07
Cotton-seed meal	9.22	6.81	7.43	8.37	39.50	28.67	2.89	.31
Clover meal	12.04	7.19	23.00	2.66	15.38	39.73	.49	1.59
Bone and meat meal	7.17	33.86	0.00	8.03	42.63	8.31	13.55	17.09
Granulated milk	11.08	24.00	0.00	1.22	44.69	19.01	7.68	12.39
Wheat bran	10.27	6.37	10.34	4.70	15.06	53.26	3.15	.19
Bone ash	......	......	......	......	......	......	40.76	52.79

THE EFFECT OF THE ADDITION OF SODIUM TO DEFICIENT AMOUNTS OF POTASSIUM, UPON THE GROWTH OF PLANTS IN BOTH WATER AND SAND CULTURES.

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AND

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The field experiment which was inaugurated in 1894 at the Rhode Island Station to study the effects upon plant growth of adding potassium and sodium in different relative amounts, both as chlorids and carbonates, demonstrated, among other things, that when a deficient amount of potassium was supplemented by a liberal amount of sodium, a considerable increase in yield resulted with certain plants, and that the increased yield was accompanied, in nearly all cases, by an increase in the percentage of sodium in the crop and a decrease in the percentage of potassium. The relative depression in the latter, however, which resulted when extra sodium was added, was not so great in most cases as the relative increase in yield, so that there was, therefore, more potassium actually removed from the soil of a given area by the crop, even though the percentage in the plant was less. It is difficult under such circumstances to disprove that the sodium may not have been beneficial primarily because of its recognized ability to increase the amount of available potassium; although much evidence was presented in the last annual

* While detailed at the Rhode Island Agricultural Experiment Station for coöperative work.

report of the Rhode Island Station, resulting from a study of the ash analyses of the field crops, that sodium was probably beneficial primarily in some other way than as a liberator of potassium.

The desirability of conducting water-culture experiments so that the available potassium could be limited to a definite amount, led to the coöperative work which is here recorded.

The water cultures were conducted in wide-mouthed glass bottles which had a capacity of about 250 cubic centimeters and which possessed a high degree of resistance to the solvent action of the solutions. The seeds were usually germinated upon a perforated paraffin disk, which was floated upon a pan of water. When the plumules had attained a length of about three centimeters, ten selected seedlings were suspended from the flat cork of each bottle by placing them in V-shaped notches in the periphery of the cork, and holding them in place by the removed portions of the cork and a rubber band.* This arrangement reduced the evaporation from the solution to a minimum, so that the loss of water during a given time would represent practically the amount transpired. Each bottle was covered with a piece of thick black paper to exclude the light from the roots.

The water used in making the nutrient solutions had been distilled, and treated with carbon black. The salts were the ordinary c. p. chemicals. The solutions in which the plants grew were usually replaced by fresh ones every three or four days, at which time the loss in weight could be recorded. The total number of grams of water transpired during the last three or four periods, constituted the transpiration as recorded in the succeeding tables. The green weights, which are recorded in grams, represent the portion of the plants above the juncture of the roots with the tops. The discussion of the effect of either sodium or calcium in the presence of a deficiency of potassium will deal principally with the green weights, because of the fact that, due to the extra salt in solution, the increase in transpiration is often relatively less than the increase in green weight.

* A simple method for experiments with water culture. The Plant World, 9, 13, (1906).

The solutions which contained about 450 parts per million of solids included, in part, the following kinds and amounts of salts in all cases:

Calcium nitrate $Ca\,(NO_3)_2$, 244 parts per million (p. p. m.).
Magnesium sulfate, $Mg\,SO_4$, 96 p. p. m.
Mono-calcium phosphate, $Ca\,H_4\,(PO_4)_2$, 58 p. p. m.
Ferric nitrate, $Fe_2\,(NO_3)_6$, trace.

The above salts furnished 70 p. p. m. of calcium (Ca), 19 p. p. m. of magnesium (Mg), 42 p. p. m. of nitrogen (N), 15 p. p. m. of phosphorus (P), and 26 p. p. m. of sulfur. They were supplemented in different series by the following kinds and amounts of salts which are recorded in connection with the tables containing the results of the individual experiments, namely: 32 p. p. m. of potassium (K), the usual maximum amount which was employed in connection with the above quantities, furnished in 61 p. p. m. of potassium chlorid (K Cl), 71 p. p. m. of potassium sulfate ($K_2\,SO_4$), or 57 p. p. m. of potassium carbonate ($K_2\,CO_3$); 18 p. p. m. of sodium (Na), the equivalent of the above potassium, contained in 48 p. p. m. of sodium chlorid (Na Cl), 58 p. p. m. of sodium sulfate ($Na_2\,SO_4$), or 44 p. p. m. of sodium carbonate ($Na_2\,CO_3$); or 16 p. p. m. of calcium, the equivalent of the potassium and the sodium, contained in 45 p. p. m. of calcium chlorid ($Ca\,Cl_2$). Whenever the sulfates of sodium or calcium were used to supplement the potassium they were added in equal, instead of chemically equivalent, amounts; 17 p. p. m. of calcium in calcium sulfate ($Ca\,SO_4$), were compared for example with 16 p. p. m. of sodium in sodium sulfate; each was obtained from 58 p. p. m. of its respective salt.

The general scheme of the experiments was to replace three-fourths or seven-eighths of the maximum amount of potassium by equivalent amounts of sodium, or extra calcium, in certain of the series; which would lead, of course, to slight variations in the amount of total solids in the different series. In certain of the experiments, as will be indicated in connection with the same, the amount of solids was halved or doubled as the case might be, which led to a

corresponding change in the above-mentioned amounts of those salts which constituted the foundation nutrients common to all of the experiments. The solution which was used in most of the experiments contained about 450 p. p. m. of solids. Slight variations from this amount do not affect the growth. The wheat which was used was the Russian variety known as "Chul."

Experiment I.

Wheat Grown from April 26 *to May* 19, 1906.

(Solids, about 450 p. p. m. of solution.)

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
32 p. p. m. of K in K Cl.....	405 387	7.28 7.30	396	7.29	100	100
8 p. p. m. of K in K Cl......	336 306	5.10 4.71	321	4.91	81	67
8 p. p. m. of K in K Cl, and 14 p. p. m. of Na in Na Cl....	357 342	5.98 5.36	350	5.67	88	78
8 p. p. m. of K in K Cl, and 12 p. p. m. of Ca in Ca Cl_2 ...	297 296	4.99 4.58	297	4.78	75	66
4 p. p. m. of K in K Cl......	291 284	5.00 4.74	288	4.87	73	67
4 p. p. m. of K in K Cl, and 16 p. p. m. of Na in Na Cl....	306 319	5.49 4.99	313	5.24	79	72
4 p. p. m. of K in K Cl, and 14 p. p. m. of Ca in Ca Cl_2 ...	280 293	4.60 4.93	287	4.77	72	65

The above results show plainly that there was a deficiency of potassium when only 8 and 4 parts per million were added, and that

the yields were increased when these amounts were supplemented by sodium; but that the extra calcium, which was used in amounts equivalent to the sodium, did not increase the growth.

EXPERIMENT II.

Wheat Grown from May 16 *to June* 7, 1906.

(Solids, about 450 p. p. m. of solution.)

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
32 p. p. m. of K in K Cl.....	396 419	6.12 6.53	408	6.34	100	100
8 p. p. m. K in K Cl.........	368 378	5.22 5.65	373	5.44	91	86
8 p. p. m. K in K Cl, and 14 p. p. m. Na in Na Cl......	392 390	5.66 5.60	391	5.63	96	89
8 p. p. m. of K in K Cl, and 12 p. p. m. of Ca in $CaCl_2$...	351 352	5.16 5.58	352	5.37	86	85
4 p. p. m. of K in K Cl......	339 308	4.56 4.31	324	4.44	79	70
4 p. p. m. of K in K Cl, and 16 p. p. m. of Na in Na Cl....	371 398	5.28 5.99	385	5.64	94	89
4 p. p. m. of K in K Cl, and 14 p. p. m. of Ca in $CaCl_2$..	323 331	4.97 4.60	327	4.79	80	76

A slight gain is indicated above, when 8 parts per million of potassium were supplemented by sodium, but not when supplemented by calcium. A large gain resulted, however, when sodium was added to the smallest amount of potassium; and, in this particular instance, the extra calcium increased the yield slightly.

Experiment III.

Wheat Grown from May 4 to May 26, 1906.

(Solids, about 225 p. p. m. of solution.)

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
16 p. p. m. of K in K Cl.....	432 471	5.78 6.20	452	5.99	100	100
4 p. p. m. of K in K Cl......	356 354	4.50 4.43	355	4.47	79	75
4 p. p. m. of K in K Cl, and 7 p. p. m. of Na in Na Cl.....	443 382	5.85 5.37	413	5.61	91	94
4 p. p. m. of K in K Cl, and 6 p. p. m. of Ca in Ca Cl_2....	410 348	5.35 4.76	379	5.06	84	84
2 p. p. m. of K in K Cl......	362 335	4.17 4.23	349	4.20	77	70
2 p. p. m. of K in K Cl...... 8 p. p. m. of Na in Na Cl.....	355 329	4.88 4.45	342	4.67	76	78
2 p. p. m. of K in K Cl...... 7 p. p. m. of Ca in Ca Cl_2....	299 340	3.90 4.43	320	4.17	71	70

In the above experiment, the amounts of nutrients were only half as large as in the preceding two experiments. When a quarter of the potassium was supplemented by sodium a marked increase in growth was obtained; and even with the addition of the extra calcium there was a slight gain.

When one-eighth of the potassium, or only 2 p. p. m., was supplemented by sodium there was no gain in transpiration, although each bottle yielded a greater green weight. The calcium, however, increased neither the green weight nor the transpiration.

A second experiment, with the same kinds and amounts of nutrients, follows:

EXPERIMENT IV.

Wheat Grown from May 11 *to June* 4, 1906.

(Solids, about 225 p. p. m. of solution.)

SPECIAL ADDITIONS.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
16 p. p. m. of K in K Cl.....	507 490	5.59 5.64	499	5.61	100	100
4 p. p. m. of K in K Cl......	440 411	4.77 4.30	426	4.54	85	81
4 p. p. m. of K in K Cl, and 7 p. p. m. of Na in Na Cl....	475 439	5.27 4.84	457	5.06	92	90
4 p. p. m. of K in K Cl, and 6 p. p. m. of Ca in $CaCl_2$....	427 446	4.55 4.53	437	4.54	89	81
2 p. p. m. of K in K Cl......	386 352	4.41 4.18	369	4.30	73	75
2 p. p. m. of K in K Cl, and 8 p. p. m. of Na in Na Cl....	391 450	4.35 4.47	421	4.41	84	79
2 p. p. m. of K in K Cl. and 7 p. p. m. of Ca in $CaCl_2$....	382 413	4.43 4.34	398	4.39	79	78

The addition of 7 p. p. m. of sodium to the 4 p. p. m. of potassium again increased the green weight from each bottle, whereas no increase in weight resulted from the addition of the extra calcium.

When added to the 2 p. p. m. of potassium, both the sodium and the calcium increased the average growth slightly, although in each case the smallest yield secured from one of the bottles was slightly less than the largest yield when potassium alone was used.

It was evident, from the appearance of the plants, that they suffered materially in the last two experiments when the solids were as low as 225 p. p. m. of solution and the potassium was reduced to 4 and 2 p. p. m. Under such conditions it is probable that the functions which only potassium could perform, were so improperly exercised that any beneficial effect which sodium might ordinarily exert, by fulfilling some function which is usually, although perhaps not necessarily, performed by potassium, would not be so prominently shown as would be the case were the potassium less deficient. It was decided that the amount of solids could not be advantageously reduced to such low limits when other conditions were suitable for rapid growth.

Having secured repeated indications from the foregoing experiments, that sodium was beneficial in connection with deficient amounts of potassium, when the seeds were left upon the seedlings, it was desired to ascertain whether the removal of the seeds would lead to a greater benefit due to sodium. The two experiments which follow, deal with this question.

EXPERIMENT V.

Wheat Grown from May 25 to June 12, 1906.

(Solids, about 450 p. p. m. of solution.)

SPECIAL ADDITIONS.	FROM EACH BOTTLE.				AVERAGE PER BOTTLE.				RELATIVE.			
	Transpiration.		Green weight.		Transpiration.		Green weight.		Transpiration.		Green weight.	
	Seeds removed.	Not removed.	Seeds removed.	Not removed.	Seeds removed.	Not removed.	Seeds removed.	Not removed.	Seeds removed.	Not removed.	Seeds removed.	Not removed.
32 p. p. m. of K in K Cl.........	261 287	287 283	6.08 6.17	6.72 6.70	274	285	6.13	6.71	100	100	100	100
32 p. p. m. of K in K Cl, and 16 p. p. m. of Na in $Na_2 SO_4$.....	261 266	294 282	6.55 6.68	7.29 7.00	264	288	6.62	7.15	96	101	108	107
32 p. p. m. of K in K Cl, and 17 p. p. m. of Ca in $Ca SO_4$.......	259 267	265 267	6.69 6.57	6.62 6.47	263	266	6.63	6.55	96	94	108	98
8 p. p. m. of K in K Cl..........	163 164	198 181	3.73 3.49	4.32 3.75	164	189	3.61	4.04	60	67	59	60
8 p. p. m. of K in K Cl, and 12 p. p. m. of Na in $Na_2 SO_4$.....	196 215	234 244	4.23 4.24	5.15 5.24	206	239	4.24	5.20	75	84	69	78
8 p. p. m. of K in K Cl, and 13 p. p. m. of Ca in $Ca SO_4$.....	190 179	223 203	3.66 3.30	4.61 3.93	185	213	3.48	4.27	67	75	57	64

In this experiment, in order to secure the results recorded in the columns marked "seeds removed," the seeds were detached two and one-half days after the seedlings were placed in the corks. These figures may be compared with those in the columns headed "not removed," which represent the results obtained when the seeds were left on, as was usual in most of the experiments recorded in this article. All other conditions were identical.

In this experiment the sulfates of sodium and calcium were used instead of the chlorids, for supplementing the potassium.

The addition of either sodium sulfate or calcium sulfate to the full ration of potassium chlorid, did not increase the *transpiration*, whether the seeds were removed or not; but, according to the *green weights*, there was a slight gain in both cases, when sodium sulfate was added, although calcium sulfate gave an increase only when the seeds were removed.

When the amount of potassium was decreased to 8 p. p. m., the increases caused by the addition of sodium sulfate were of such magnitude, measured both by the figures for transpiration and green weight, that there could be no question of their reality. It is interesting to note in this connection that no increased gains were caused by the sodium sulfate as a result of removing the seeds from the plants.

Although the increase in transpiration when the calcium sulfate was added with the smaller amount of potassium was one-half as much as when the sodium sulfate was added, whether the seeds were or were not removed, there was no positive gain in the green weights.

EXPERIMENT VI.

Wheat Grown from June 29 to July 14, 1906.

(Solids, about 450 p. p. m. of solution.)

Special Additions.	From Each Bottle.				Average Per Bottle.				Relative.			
	Transpiration.		Green weight.		Transpiration.		Green weight.		Transpiration.		Green weight.	
	Seeds removed.	Not removed.	Seeds removed.	Not removed.	Seeds removed.	Not removed.	Seeds removed.	Not removed.	Seeds removed.	Not removed.	Seeds removed.	Not removed.
32 p. p. m. of K in K Cl	....	271 253	....	7.40 7.30	......	262	......	7.35	......	100	......	100
32 p. p. m. of K in K Cl, and 16 p. p. m. of Na in $Na_2 SO_4$	....	253 237	....	8.08 7.90	......	245	......	7.99	......	94	......	109
32 p. p. m. of K in K Cl, and 17 p. p. m. of Ca in Ca SO_4	....	234 222	....	7.04 7.16	......	228	......	7.10	......	87	......	97
8 p. p. m. of K in K Cl	166 147	189 195	4.09 3.94	4.67 4.96	157	192	4.02	4.82	60	73	54	65
8 p. p. m. of K in K Cl, and 12 p. p. m. of Na in $Na_2 SO_4$	149 162	234 205	4.19 4.02	5.78 5.26	156	220	4.11	5.52	60	82	56	75
8 p. p. m. of K in K Cl, and 13 p. p. m. of Ca in Ca SO_4	149 142	197 222	3.87 3.53	4.83 4.95	146	210	3.70	4.89	56	80	50	67

In a part of the above experiment it may be seen that the seeds were again detached, but in this instance only eighteen hours elapsed after placing the seedlings in the bottles, before the seeds were removed, instead of two and one-half days as in the previous experiment.

The treatment was identical in those portions of the two preceding tables which contain the results with 8 p. p. m. of potassium alone, and supplemented by either sodium or calcium sulfate; and, if the possible influence of the weather conditions be left out of consideration, it is possible to compare the relative effect of removing the seeds at the two stages of growth. The depression in the green weights caused by removing the seeds two and one-half days after placing the plants in the corks (experiment V), was 11, 18, and 19 per cent., respectively, in the three series under consideration; whereas, the depression in experiment VI, when the seeds were detached after only eighteen hours, was 17, 26, and 24 per cent. These figures suggest a considerable disturbance of the plants by the removal of the seeds in both cases, and that the disturbance was greater, when the seeds were detached early. In fact, the appearance of the plants from which the seeds were removed after only eighteen hours, was such as to make it seem undesirable to remove the seeds unless some special advantage was to be gained in the study of the main problem under consideration.

The relative effect of the addition of sodium sulfate and of calcium sulfate to a deficient amount of potassium (8 p. p. m.) upon wheat plants from which the seeds had, and had not, been removed, may be seen by a study of the green weights in the two preceding tables. The addition of the sodium sulfate to the small amount of potassium, when the seeds were not removed, increased the green weights 29 and 15 per cent., respectively, in experiments V and VI; but, on the other hand, when the seeds were removed, the increase from the sodium sulfate was only 17 and 2 per cent., respectively. It appeared, therefore, that probably nothing would be gained by removing the seeds, towards accentuating the benefits derived from sodium in

case of a lack of potassium. Insignificant gains resulted when the calcium sulfate was used, and the seeds were left on, and insignificant losses when they were removed. Another instance is afforded here of practically no effect from the extra calcium when the potassium was deficient, but, on the whole, of considerable increase from the sodium.

In connection with the larger amount of potassium, experiment VI shows that whereas there was a gain in green weight of 9 per cent. when sodium was added, there was a slight depression when calcium was added, both elements having been supplied in equal amounts of sulfates.

EXPERIMENT VII.

Wheat Grown from August 16 *to* 31, 1906.

(Solids, about 450 p. p. m. of solution.)

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		AVERAGE PER BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
32 p. p. m. of K in K Cl.....	350 362	7.78 8.18	356	7.98	100	100
32 p. p. m. of K in K Cl, and 16 p. p. m. of Na in $Na_2 SO_4$.	309 335	7.67 7.74	322	7.70	90	97
32 p. p. m, of K in K Cl, and 17 p. p. m. of Ca in $Ca SO_4$..	293 335	7.47 8.27	314	7.87	88	99
8 p. p. m. of K in K Cl......	246 250	5.37 5.29	248	5.33	70	67
8 p. p. m. of K in K Cl, and 12 p. p. m. of Na in $Na_2 SO_4$..	309 314	6.43 6.30	311	6.37	88	80
8 p. p. m. of K in K Cl, and 13 p. p. m. of Ca in $Ca SO_4$...	270 267	5.60 5.53	268	5.56	75	70

The above results show that no gain resulted by adding either sodium sulfate or calcium sulfate to the full ration of potassium; but that when the amount of potassium was reduced to 8 p. p. m., or enough to depress the yield about 30 per cent., a decided increase resulted from the addition of sodium sulfate, although an equal amount of calcium sulfate produced only a slight gain.

In experiments V, VI, and VII, a slight apparent gain in green weight resulted whenever 13 p. p. m. of calcium in calcium sulfate were added to the smaller amount of potassium, although this was not always borne out by the transpiration, and was, perhaps, within the limit of error. Nevertheless it was deemed advisable, in view of the fact that an amount of calcium sulfate equal to that of sodium sulfate would be expected to exert less osmotic pressure, to increase the quantity of calcium sulfate, so that twice as much of it would be present as of the sodium sulfate. The experiments which will now be considered were designed to show the effect of this change.

EXPERIMENT VIII. (See figure 1.)

Wheat Grown from July 11 *to* 27, 1906.

(Solids, about 450 p. p. m. of solution.)

Series	Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
		Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
1	32 p. p. m. of K in K Cl...	192 191	8.26 7.73	192	8.00	100	100
2	32 p. p. m. of K in K Cl, and 16 p. p. m. of Na in $Na_2 SO_4$	192 192	8.23 7.68	192	7.96	100	100
3	32 p. p. m. of K in K Cl, and 34 p. p. m. of Ca in Ca SO_4..	191 182	8.40 7.95	187	8.17	97	102
4	8 p. p. m. of K in K Cl.....	138 133	4.74 4.54	136	4.64	71	58
5	8 p. p. m. of K in K Cl, and 12 p. p. m. of Na in $Na_2 SO_4$	164 163	6.06 5.67	164	5.87	85	73
6	8 p. p. m. of K in K Cl, and 26 p. p. m. of Ca in Ca SO_4.	137 144	4.83 5.12	140	4.98	73	62

The above experiment agreed with the preceding one in that the only significant increase in connection with the deficient amount of potassium occurred when it was supplemented by the sodium, in spite of the fact that the quantity of calcium sulfate had been doubled. It is difficult to understand how the increase in growth caused by the sodium could be attributed to greater osmotic pressure, for otherwise such liberal amounts of calcium sulfate would be expected to exert a similar effect.

In the experiments heretofore reported the amount of solids has usually been about 450 p. p. m. of solution, but in the one which

follows, the foundation nutrients were doubled whereas the special additions, as given in the following table, remained unchanged except that a series was introduced in which 64 p. p. m. of potassium were present.

Experiment IX.

Wheat Grown from July 17 to August 1, 1906.

(Solids, about 800 p. p. m. of solution.)

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
64 p. p. m. of K in K Cl.....	173 174	7.14 7.15	174	7.15	100	100
32 p. p. m. of K in K Cl.....	153 158	6.43 6.30	155	6.37	90	88
32 p. p. m. of K in K Cl, and 16 p. p. m. of Na in Na_2SO_4.	162 164	7.01 6.70	163	6.85	94	96
32 p. p. m. of K in K Cl, and 34 p. p. m. of Ca in Ca SO_4...	178 169	6.69 7.03	174	6.86	100	96
8 p. p. m. of K in K Cl.......	147 159	4.73 4.60	153	4.67	88	65
8 p. p. m. of K in K Cl, and 12 p. p. m. of Na in Na_2SO_4..	163 188	5.46 5.68	176	5.57	101	78
8 p. p. m. of K in K Cl, and 26 p. p. m. of Ca in Ca SO_4...	141 156	4.67 5.11	148	4.89	85	68

It may be seen by reference to the foregoing table that an increase in the usual maximum amount of potassium to 64 p. p. m. resulted in the maximum green weight. In other words, 32 p. p. m. of potassium, in connection with the large amounts of the foundation nutrients used in this case, were not sufficient for a maximum production. It is probable that 32 p. p. m. were not always sufficient, under ideal climatic conditions, to produce a maximum gowth even when the amounts of the other nutrients were not doubled, and that the frequent small increases in growth which resulted when sodium was added to this amount of potassium were due to this fact; for the results as a whole have not shown that sodium was beneficial in the presence of an abundance of potassium, but only when the latter was deficient.

It is shown by the table that sodium increased the crop as usual when supplementing 8 p. p. m. of potassium, whereas calcium did not do so with certainty, the transpiration having been even reduced.

No indications were furnished by this experiment that the specific effect of sodium in connection with a deficiency of potassium, was altered by doubling the amounts of the general nutrients.

In the preceding experiments the special additions were potassium chlorid supplemented by either the chlorids or sulfates of sodium or calcium, whereas, in the next two experiments potassium sulfate was used in place of potassium chlorid as the source of potassium.

EXPERIMENT X.

Wheat Grown from July 5 to 20, 1906.

(Solids, about 450 p. p. m. of solution.)

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		AVERAGE PER BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
32 p. p. m. of K in K_2SO_4...	297 314	6.17 6.72	306	6.45	100	100
32 p. p. m. of K in K_2SO_4, and 16 p. p. m. of Na in Na_2SO_4..	289 310	6.27 6.90	299	6.59	98	102
32 p. p. m. of K in K_2SO_4, and 34 p. p. m. of Ca in $CaSO_4$...	314 321	6.74 6.83	318	6.79	104	105
8 p. p. m. of K in K_2SO_4....	245 238	4.90 4.72	242	4.81	79	75
8 p. p. m. of K in K_2SO_4, and 12 p. p. m. of Na in Na_2SO_4...	282 273	5.15 5.56	278	5.36	91	82
8 p. p. m. of K in K_2SO_4, and 26 p. p. m. of Ca in $CaSO_4$...	248 247	4.58 4.89	248	4.74	81	74

EXPERIMENT XI.

Wheat Grown from July 27 to August 8. 1906.

(Solids, about 450 p. p. m. of solution.)

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		AVERAGE PER BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
32 p. p. m. of K in K_2SO_4....	161 141	4.84 3.95	151	4.40	100	100
8 p. p. m. of K in K_2SO_4.....	114 122	3.16 3.26	118	3.21	78	73
8 p. p. m. of K in K_2SO_4, and 12 p. p. m. of Na in Na_2SO_4..	142 163	3.64 3.59	153	3.62	101	82
8 p. p. m. of K in K_2SO_4, and 26 p. p. m. of Ca in $CaSO_4$...	148 131	3.44 3.23	139	3.34	92	76

From the figures recorded in the two preceding tables it may be seen that the average increase in green weight due to the addition of sodium sulfate to 8 p. p. m. of potassium, was about 11 per cent., whereas the addition of twice as much calcium sulfate did not cause any positive increase.

The universal increase of crop which resulted whenever sodium supplemented deficient amounts of potassium led not only to an examination of the sodium salts, which gave assurance that the effect was not due to the presence of potassium as an impurity, but also to an inquiry as to whether the sodium salts acted upon the bottles and liberated potassium, even though the calcium salts did not.

To settle this latter point, some of the bottles were completely covered with paraffin on the inside, so that the solution could not come in contact with the glass. The two succeeding experiments were conducted in such paraffined bottles.

EXPERIMENT XII.

Wheat Grown from July 27 to August 8, 1906.

(Solids, about 450 p. p. m. of solution.)

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		AVERAGE PER BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
8 p. p. m. of K in K_2SO_4....	121 119	2.82 3.01	120	2.92	100	100
8 p. p. m. of K in K_2SO_4, and 12 p. p. m. of Na in Na_2SO_4..	125 144	3.18 3.29	135	3.23	113	111
8 p. p. m. of K in K_2SO_4, and 26 p. p. m. of Ca in $CaSO_4$...	128 119	2.91 2.88	123	2.90	103	99

EXPERIMENT XIII.

Wheat Grown from August 16 *to* 31, 1906.

(Solids, about 450 p. p. m. of soluti on.)

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
8 p. p. m. of K in K Cl......	260 260	5.31 5.30	260	5.30	100	100
8 p. p. m. of K in K Cl, and 12 p. p. m. of Na in Na_2SO_4..	318 256	6.18 5.25	288	5.71	111	108

It may be seen by reference to the above tables that there was an increase of about ten per cent., in transpiration and green weight, when the deficient amount of potassium, whether in chlorid or sulfate, was supplemented by sodium sulfate; in spite of the fact that the bottles were covered with paraffin, which would preclude the possibility of the liberation of potassium from the glass, by the action of the sodium salt.

Calcium sulfate was used in one of the series of experiment XII, but it failed as usual to produce a gain.

In view of the persistent gains from the use of sodium in connection with a deficient amount of potassium, when the kinds and amounts of the foundation nutrients employed were those which experience had shown were adapted to the satisfactory growing of wheat seedlings, it seemed desirable to change the relation of the amounts of these nutrients in order to see if sodium would still prove beneficial. The amounts of the foundation nutrients employed in certain of the experiments previously recorded, were equal to one-half and again to twice those used in connection with the usual solution containing about 450 p. p. m., thus giving rise to a wide variation in the ratio between the potassium and the general foundation nutrients; but, aside from the special addition of calcium, recorded in the

tables, the *relative* amounts of calcium, magnesium, phosphorus, and nitrogen remained unchanged. It was deemed wise, therefore, in view of the importance which is frequently attributed to a certain physiological balance of the elements, to conduct the following experiments for studying this question in connection with its bearing upon the effects of sodium.

EXPERIMENT XIV.

Wheat Grown from September 10 *to* 24, 1906.

(Solids, 450 to 800 p. p. m. of solution.)

		Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
			Transpiration	Green weight.	Transpiration	Green weight.	Transpiration	Green weight.
Usual amount N.	Usual amount P.	32 p. p. m. K in K Cl......	221 227	5.84 5.93	224	5.89	100	100
		8 p. p. m. K in K Cl.......	147 175	4.06 4.32	161	4.19	72	71
		8 p. p. m. K in K Cl. and 12 p. p. m. Na in Na_2SO_4...	169 155	4.40 4.32	162	4.36	72	74
	Twice usual amt. P.	8 p. p. m. K in K Cl.......	148 162	4.13 4.00	155	4.06	70	69
		8 p. p. m. K in K Cl, and 12 p. p. m. Na in Na_2SO_4..	164 165	4.13 4.23	165	4.18	74	71
Twice usual amount N.	Usual amt. P.	8 p. p. m. K in K Cl.......	153 142	4.12 4 10	147	4.11	66	70
		8 p. p. m. K in K Cl, and 12 p. p. m. Na in Na_2SO_4..	137 153	4.13 4.23	145	4.18	65	71
	Twice usual amt. P.	8 p. p. m. K in K Cl.......	145 136	4.04 3.64	140	3.84	63	65
		8 p. p. m. K in K Cl and 12 p. p. m. Na in Na_2SO_4..	163 148	4.50 4 06	156	4.28	70	73

The table shows the effect of an addition of sodium to a deficient amount of potassium in connection with the different relative amounts of calcium nitrate and mono-calcium phosphate, the amount of magnesium sulfate remaining unchanged. It should be noticed at the outset that the effect of sodium in this particular experiment was much less in connection with the usual amounts of nitrogen and phosphorus than in the experiments recorded previously; in fact, the transpiration was not increased at all by the addition of sodium, and the green weight only slightly. Had the increase due to sodium been as marked as usual, there would, perhaps, have been more opportunity for the variations in the relation of the nitrogen and phosphorus to have exerted an appreciable effect upon that increase.

Under the circumstances, the only gain of sufficient magnitude to be of a positive nature in the four instances when sodium was used to supplement the small amount of potassium, occurred in the last comparison, when the usual amounts of nitrogen and phosphorus were both doubled. Here the increase in transpiration and green weight amounted to 12 per cent.

The results show that doubling the usual amount of nitrogen and again of phosphorus exerted only a slight influence, but it was sufficiently uniform in direction to warrant a passing notice. The average green weights in three of the four instances where comparisons are possible, were slightly less when the amount of nitrogen was doubled. The same was true when the phosphorus was doubled.

The effect of doubling the amounts of both phosphorus and nitrogen admit of the following observations: in connection with the deficient amount of potassium, without sodium, there was a considerable depression in the *average* green weight, namely: from 4.19 to 3.84 grams; whereas, there was scarcely any depression when the sodium was also present.

These results indicate that, in connection with 8 p. p. m. of potassium, the amounts of nitrogen and phosphorus, which were usually employed were at least sufficient to meet the requirements of the plants.

Experiments XV and XVI, which are next recorded, not only present some data as to the effect of increasing the amount of magnesium, but they also furnish an opportunity for studying the effect of doubling the amounts of nitrogen and phosphorus in connection with twice the amount of magnesium previously used.

EXPERIMENT XV.

Wheat Grown from October 2 to 18, 1906.

(Solids, 450 to 800 p. p. m. of solution.)

	SPECIAL ADDITIONS.	FROM EACH BOTTLE.		AVERAGE. PER BOTTLE.		RELATIVE.	
		Transpiration	Green weight.	Transpiration	Green weight.	Transpiration	Green weight.
Usual amount N. and P.	*Usual amount of Mg.*						
	32 p. p. m. K in K Cl........	210 190	5.40 5.17	200	5.27	100	100
	Twice usual amount Mg.						
	32 p. p. m. K in K Cl........	232 207	6.04 5.59	219	5.81	109	111
	8 p. p. m. K in K Cl.........	195 187	4.61 4.56	191	4.58	95	87
	8 p. p. m. K in K Cl, and 12 p. p. m. Na in Na_2SO_4.....	181 180	4.36 4.43	181	4.40	90	83
Twice usual amount N. and P.	*Usual amount of Mg.*						
	8 p. p. m. K in K Cl.........	167 171	3.93 4.42	169	4.18	84	79
	8 p. p. m. K in K Cl, and 12 p. p. m. Na in Na_2SO_4.....	167 183	4.12 4.12	175	4.12	87	78
	Twice usual amount of Mg.						
	8 p. p. m. K in K Cl.........	176 174	4.25 4.24	175	4.25	87	81
	8 p. p. m. K in K Cl, and 12 p. p. m. Na in Na_2SO_4....	175 177	4.70 4.27	176	4.49	88	85

EXPERIMENT XVI.

Wheat Grown from November 13 to 30, 1906.

(Solids, 450 to 800 p. p. m. of solution.)

	Special Additions.	From Each Bottle. Transpiration	From Each Bottle. Green weight.	Average Per Bottle. Transpiration	Average Per Bottle. Green weight.	Relative. Transpiration	Relative. Green weight.
Usual amount N. and P.	*Usual amount of Mg.*						
	32 p. p. m. K in K Cl........	149 153	3.94 4.28	151	4.11	100	100
	Twice usual amount of Mg.						
	32 p. p. m. K in K Cl........	141 153	3.32 4.65	147	3.98	97	97
	8 p. p. m. K in K Cl.........	159 132	3.64 3.28	146	3.46	96	84
	8 p. p. m. K in K Cl, and 12 p. p. m. Na in $Na_2 SO_4$	147 138	3.58 3.44	142	3.51	94	85
Twice usual amount N. and P.	*Usual amount of Mg.*						
	8 p. p. m. K in K Cl.........	151 167	3.85 3.47	159	3.66	105	89
	8 p. p. m. K in K Cl, and 12 p. p. m. Na in $Na_2 SO_4$	176 150	3.79 3.65	163	3.72	108	91
	Twice usual amount of Mg.						
	8 p. p. m. K in K Cl.........	152 150	3.42 3.60	151	3.51	100	85
	8 p. p. m. K in K Cl, and 12 p. p. m. Na in $Na_2 SO_4$.....	150 145	3.34 3.75	148	3.55	98	86

Experiment XV indicated a depression in yield when the usual amount of nitrogen and phosphorus was doubled, in connection with twice the usual amount of magnesium and 8 p. p. m. of potassium

unsupplemented by sodium; whereas experiment XVI indicated slightly the reverse. When the potassium was supplemented by sodium, however, there was no average depression caused in case of either experiment by adding extra nitrogen and phosphorus. On the whole it does not appear that the amounts of phosphorus and nitrogen, which have been used in most of the experiments, were unsuited to the needs of the plants.

The effect of doubling the amount of magnesium in connection with twice the usual amount of nitrogen and phosphorus was slight in both experiments, and as it did not exert itself in the same direction in each case, no further mention of it is warranted.

Six opportunities are afforded by the two experiments under discussion, for comparing the yields when 8 p. p. m. of potassium were used alone, with those when the same amount was supplemented by sodium, but whenever there was an apparent benefit from sodium, it was so slight as to scarcely exceed the limit of error. Attention should be called to the fact that the last three experiments were conducted after the tenth of September, when climatic conditions had changed considerably, and were unsatisfactory for rapid growth of the plants. It may be noticed that the depression in growth caused by using the one-fourth ration (8 p. p. m.) of potassium was less than formerly, indicating that under such poor conditions for growth, the deficiency of this element may not have been sufficiently great to bring out the usual helpful influence of the sodium.

The two experiments which follow show the effects of not only doubling but quadrupling the amount of magnesium, in connection with the small amount of potassium supplemented by sodium.

Experiment XVII.

Wheat Grown from September 15 *to October* 1, 1906.

(Solids, about 450 to 700 p. p. m. of solution.)

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Trans-piration.	Green weight.	Trans-piration.	Green weight.	Trans-piration.	Green weight.
32 p. p. m. of K in K Cl......	310 321	6.64 7.00	315	6.82	135	147
8 p. p. m. of K in K Cl....	228 237	4.61 4.65	233	4.63	100	100
8 p. p. m. of K in K Cl, and 12 p. p. m. of Na in $Na_2 SO_4$..	272 229	5.05 4.59	250	4.82	107	104
8 p. p. m. of K in K Cl..... 12 p. p. m. of Na in $Na_2 SO_4$, and an extra ration of Mg.	282 265	5.21 5.01	273	5.11	117	110
8 p. p. m. of K in K Cl..... 12 p. p. m. of Na in $Na_2 SO_4$, and three extra rations of Mg.	217 217	4.46 4.60	217	4.53	93	98

EXPERIMENT XVIII.

Wheat Grown from September 25 *to October* 11, 1906.

(Solids, about 450 to 700 p. p. m. of solution.)

Special Additions.	From Each Bottle.		Average. Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
8 p. p. m. K in K Cl.......	195 182	4.44 4.74	189	4.59	100	100
8 p. p. m. K in K Cl, and 12 p. p. m. Na in Na_2 SO_4...	179 191	4.88 5.06	185	4.97	98	109
8 p. p. m. K in K Cl....... 12 p. p. m. Na in Na_2SO_4, and an extra rations of Mg.	190 178	4.99 4.83	184	4.91	98	107
8 p. p. m. K in K Cl,...... 12 p. p. m. Na in Na_2SO_4, and three extra rations of Mg.	176 180	4.52 5.02	178	4.77	95	104

In the two foregoing experiments the addition of sodium to the deficient amount of potassium resulted in an increase in the green weight.

In experiment XVII there appeared to be some benefit from doubling the magnesium, but this is the only instance in either experiment when any benefit resulted from its increase. In the last series of each experiment there was an apparent depression when the usual amount of magnesium was quadrupled.

It was previously suggested that the failure of the sodium to cause the usual increase, when supplementing 8 p. p. m. of potassium, in the case of certain of the experiments which were conducted in the fall under conditions inclined to depress photosynthesis, was possibly because this amount of potassium was not sufficiently small to result in a marked deficiency. Accordingly the following experiment was conducted in which only 4 p. p. m. of potassium were added in certain series. The only available place for conducting the experiment at

the particular time, was in the chemical laboratory, where the conditions were unfavorable for photosynthesis and where the growth was very slow.

Experiment XIX.

Wheat Grown from November 30 to December 21, 1906.

(Solids, 450 to 550 p. p. m. of solution.)

Special Additions.	From Each Bottle. Transpiration.	From Each Bottle. Green weight.	Average Per Bottle. Transpiration.	Average Per Bottle. Green weight.	Relative. Transpiration.	Relative. Green weight.
32 p. p. m. of K in K Cl.....	162 153	4.94 4.86	158	4.90	100	100
8 p. p. m. K in K Cl.......	123 123	3.43 3.78	123	3.60	78.	74
8 p. p. m. K in K Cl, and 12 p. p. m. in Na in Na_2SO_4.	122 125	3.58 3.72	124	3.65	78	75
4 p. p. m. K in K Cl.......	100 98	2.71 2.79	99	2.75	63	56
4 p. p. m. K in K Cl, and 14 p. p. m. Na in Na_2SO_4	120 117	3.27 3.53	119	3.40	75	69
Each series below had an extra ration of Mg.						
32 p. p. m. K in K Cl........	160 149	4.88 4.71	155	4.80	98	96
8 p. p. m. K in K Cl.......	120 118	3.71 3.52	119	3.61	76	74
8 p. p. m. K in K Cl, and 12 p. p. m. Na in Na_2SO_4..	123 120	3.66 3.38	122	3.52	77	72
4 p. p. m. K in K Cl........	99 103	2.76 3.01	101	2.88	64	59
4 p. p. m. K in K Cl, and 14 p. p. m. Na in Na_2SO_4	96 104	3.01 3.02	100	3.02	63	62

The above experiment shows no advantage from adding sodium to 8 p. p. m. of potassium, either with the usual, or twice the usual, amount of magnesium; in connection with only 4 p. p. m. of potassium, however, there was a distinct increase in transpiration and green weight when sodium was added and the magnesium remained as usual; yet, even with only 4 p. p. m., the advantage from sodium largely disappeared when the extra ration of magnesium was present. (Compare the last two series).

The only instance of any appreciable effect from increasing the magnesium was in connection with the 4 p. p. m. of potassium, plus sodium, when a depression occurred.

The reader may have noticed that the specific effect of sodium seems to have been frequently somewhat influenced by the amount of magnesium present, and a winter glass-house having become available, where satisfactory growth was possible, the two following duplicate experiments were conducted therein, with the hope of settling this particular phase of the question.

Experiment XX.

Wheat Grown from January 23 to February 9, 1907.

(Solids, 450 to 550 p. p. m. of solution.)

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
32 p. p. m. K in K Cl.......	177 183	4.15 4.47	180	4.31	100	100
8 p. p. m. K in K Cl.......	108 144	2.68 3.04	126	2.86	70	66
8 p. p. m. K in K Cl, and 12 p. p. m. Na in $Na_2 SO_4$....	137 152	3.06 3.23	145	3.14	81	73
4 p. p. m. K in K Cl.......	117 109	2.55 2.58	113	2.57	63	60
4 p. p. m. K in K Cl, and 14 p. p. m. Na in $Na_2 SO_4$.....	123 124	2.93 2.69	124	2.81	69	65
Each series below had an extra ration of Mg.						
8 p. p. m. K in K Cl.......	131 119	2.65 2.70	125	2.67	69	62
8 p. p. m. K in K Cl, and 12 p. p. m. Na in $Na_2 SO_4$.....	156 131	3.61 2.95	144	3.28	80	76
4 p. p. m. K in K Cl.......	107 95	2.57 2.22	101	2.40	56	56
4 p. p. m. K in K Cl, and 14 p. p. m. Na in $Na_2 SO_4$.....	147 139	3.22 2.97	143	3.10	80	72

EXPERIMENT XXI.

Wheat Grown from February 11 *to* 27, 1907.

(Solids, 450 to 550 p. p. m. of solution.)

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
32 p. p. m. K in K Cl.......	215 197	5.34 5.06	206	5.20	100	100
8 p. p. m. K in K Cl.......	148 160	3.56 4.03	154	3.79	75	73
8 p. p. m. K in K Cl, and 12 p. p. m. Na in Na_2SO_4...	182 166	4.49 4.08	174	4.29	84	83
4 p. p. m. K in K Cl.......	118 131	2.92 3.23	125	3.07	60	59
4 p. p. m. K in K Cl, and 14 p. p. m. Na in Na_2SO_4...	160 156	3.74 3.75	158	3.75	77	72
Each series below had an extra ration of Mg.						
8 p. p. m. K in K Cl.......	153 152	3.83 3.85	153	3.84	74	74
8 p. p. m. K in K Cl....... 12 p. p. m. Na in Na_2SO_4...	173 173	4.11 4.19	173	4.15	84	80
4 p. p. m. K in K Cl.......	120 104	3.29 3.06	112	3.18	54	61
4 p. p. m. K in K Cl, and 14 p. p. m. Na in Na_2SO_4...	148 138	3.58 3.30	143	3.44	69	66

It may be seen by reference to the two preceding tables that twice the customary amount of magnesium was added in the last four series of each experiment, but the only instance when this extra magnesium produced any marked effect was in connection with 4 p. p. m. of potassium, plus the sodium; and even then the effects in the two experiments were contradictory, being beneficial in the former experiment and detrimental in the latter.

In these two experiments, during which the conditions for active growth were satisfactory, the reduction in the amount of potassium to a quarter ration, resulted in a depression of from 26 to 38 per cent. in the green weight, whereas in most of the experiments conducted in the fall, under unfavorable conditions for rapid growth, the depression was much less with this amount. Sodium does not seem to act beneficially unless there is a considerable deficiency of potassium. A still further reduction of potassium to 4 p. p. m. resulted in a total depression in green weights of from 39 to 44 per cent., but the yellow color of the plants in the various series receiving this amount of potassium, but no sodium, indicated that they suffered too much from a lack of potassium. Marked gains in transpiration and green weight occurred in the eight instances in these two experiments, when deficient amounts of potassium were supplemented by sodium.

It appears, therefore, as though the occasional advantages which seemed to result from an increase in the amount of magnesium when conditions were unfavorable, do not manifest themselves under satisfactory circumstances, and that an increase in the amount of this element over that which had been used in most of the experiments, resulted on the whole in no particular advantage. It is evident, also, that additional amounts of magnesium and calcium did not offset in a positive degree the depression resulting from a reduction in the amount of potassium. The sodium, however, was of great service in this respect.

It was thought advisable to ascertain if any different conclusions would be drawn concerning the general effect of sodium, if the oven-dry weights as well as the green weights of the wheat plants were

secured. To throw light upon this matter, the oven-dry weights were obtained in addition to the green weights which were recorded in experiments XX and XXI. These are included in the following table.

Table giving the average weight of oven-dry tops and roots per bottle (ten plants) of wheat grown in experiments XX and XXI.

Special Additions.	Oven-dry Weight, Grams.				Relative.	
	Tops.		Roots.		Oven-dry tops.	
	Exp. XX.	Exp. XXI.	Exp. XX.	Exp. XXI.	Exp. XX.	Exp. XXI.
32 p. p. m. K in K Cl......	.463	.590	.202	.359	100	100
8 p. p. m. K in K Cl.......	.349	.480	.169	.261	75	81
8 p. p. m. K in K Cl, and 12 p. p. m. Na in Na_2SO_4.	.381	.517	.166	.308	82	88
4 p. p. m. K in K Cl......	.332	.467	.154	.264	72	79
4 p. p. m. K in K Cl, and 14 p. p. m. Na in Na_2SO_4.	.394	.498	.169	.289	85	84
Each series below had an extra ration of Mg.						
8 p. p. m. K in K Cl.......	.323	.368	.155	.207	70	60
8 p. p. m. K in K Cl, and 12 p. p. m. Na in Na_2SO_4.	.330	.445	.156	.254	71	75
4 p. p. m. K in K Cl......	.298	.386	.139	.227	64	65
4 p. p. m. K in K Cl, and 14 p. p. m. Na in Na_2SO_4.	.377	.414	.161	.227	81	70

The relative weights of oven-dry tops, although differing somewhat from the relative green weights previously recorded in experiments XX and XXI, as would be expected in consideration of the differences

in vigor of the plants in certain of the series, do not, nevertheless, lead to any different conclusions concerning the effect of sodium from those arrived at from an inspection of the green weights.

Calculations were made to determine the ratio of the oven-dry roots to the tops in the various series, but no constant differences in this respect appeared to result from the various additions.

In the experiments thus far recorded, in which potassium chlorid or sulfate has been supplemented by sodium chlorid or sulfate, and again by calcium chlorid or sulfate, the aim has been to reduce the amount of potassium to such an extent in certain of the series, that the added sodium would have every opportunity to be useful. It has been shown that when the potassium was omitted to such an extent as to cause a reduction in growth of about 30 per cent., the addition of sodium rarely failed to cause an increase in yield. The amount to which potassium had to be reduced in order to create a deficiency so marked that the addition of sodium resulted in a benefit, depended, as would be expected, upon the temperature and sunlight conditions. When the total solids equalled about 450 p. p. m. of solution, there was very little evidence of benefit by adding sodium to 32 p. p. m. of potassium. Under conditions for rapid growth, a reduction in potassium to one-fourth this amount (8 p. p. m.), usually caused a depression which was so marked that good results followed the addition of sodium; but under less favorable conditions the amount of potassium had to be limited to 4 p. p. m., before large gains resulted from the addition of sodium. In the experiments which will now be recorded, wherein potassium carbonate was supplemented by sodium carbonate, the amounts of potassium were so large that sodium could not be expected to act beneficially. They serve rather to present conditions under which the supplementation of potassium by sodium, results in no benefit.

Upon first making the observations that the addition of sodium to a deficient amount of potassium in solution resulted in a gain, it was thought that possibly the sodium salt had indirectly improved the reaction of the solution, and numerous titrations were made to

determine the alkalinity or acidity of the solutions in which the wheat had grown. It was found that the largest plants produced the most alkaline solutions, but that the increase in alkalinity for a given increase in growth, was the same whether the larger growth was caused by the addition of sodium or extra potassium. In other words, the extent of the alkalinity seemed to depend upon the amount of growth, regardless of whether it was caused by the addition of sodium or of potassium, to a deficient amount of the latter. Owing to the natural tendency of the wheat seedlings to change the reaction of the solution towards alkalinity, it seemed quite possible that the addition of sodium in carbonate might result in an undesirable degree of alkalinity, and in the experiments with the carbonates which follow, special attention was given to this point:

Experiment XXII.

Wheat Grown from August 4 to 18, 1906.

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight	Transpiration.	Green weight.	Transpiration.	Green weight.
Solids, about 225 p. p. m.						
32 p. p. m. K in K_2CO_3.....	246 253	4.52 4.34	249	4.43	100	100
32 p. p. m. K in K_2CO_3, and 4 p. p. m. Na in Na_2CO_3...	230 223	4.65 4.42	226	4.54	91	103
8 p. p. m. K in K_2CO_3.....	256 228	3.95 3.53	242	3.74	97	84
8 p. p. m. K in K_2CO_3, and 4 p. p. m. Na in Na_2CO_3...	257 233	3.92 3.86	245	3.89	98	88
*Solids, about 450 p. p. m.**						
64 p. p. m. K in K_2CO_3.....	237 256	5.48 5.90	246	5.69	99	128
64 p. p. m. K in K_2CO_3, and 4 p. p. m. Na in Na_2CO_3...	259 281	5.46 6.13	270	5.79	108	131
16 p. p. m. K in K_2CO_3.....	264 245	4.61 4.56	254	4.58	102	103
16 p. p. m. K in K_2CO_3, and 4 p. p. m. Na in Na_2CO_3...	251 263	4.50 4.68	257	4.59	103	104

* The amount of mono-calcium phosphate was one-half greater than usually employed with this amount of solids, which necessitated the addition of smaller amounts of sodium carbonate in order not to cause a precipitation. The same is true of experiment XXIII.

EXPERIMENT XXIII.

Wheat Grown from August 10 to 23, 1906.

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
Solids, about 225 p. p. m.						
32 p. p. m. K in K_2CO_3.....	180 182	4.78 4.56	181	4.67	100	100
32 p. p. m. K in K_2CO_3, and 4 p. p. m. Na in Na_2CO_3...	210 195	4.76 4.58	202	4.67	112	100
8 p. p. m. K in K_2CO_3.....	185 181	3.57 3.56	183	3.57	101	76
8 p. p. m. K in K_2CO_3, and 4 p. p. m. Na in Na_2CO_3...	178 194	3.61 3.49	186	3.55	103	76
Solids, about 450 p. p. m.						
64 p. p. m. K in K_2CO_3....	203 215	6.31 6.18	209	6.24	116	134
64 p. p. m. K in K_2CO_3, and 4 p. p. m. Na in Na_2CO_3...	190 238	5.43 6.65	214	6.04	118	129
16 p. p. m. K in K_2CO_3......	196 203	4.58 4.84	200	4.71	110	101
16 p. p. m. K in K_2CO_3, and 4 p. p. m. Na in Na_2CO_3...	210 213	4.70 4.88	211	4.79	117	103

In the two preceding experiments there was practically no effect upon the green weights, from the addition of such a small amount of sodium carbonate to 8 p. p. m. or more of potassium.

Potassium at the rate of 64 p. p. m., together with the usual amount of nutrients excepting that the amount of mono-calcium phosphate was increased one-half, gave about 30 per cent. more green weight, in each case, than 32 p. p. m. of this element accompanied by about one-half the total solids; in fact the weights in the latter case were no larger than were secured by using 16 p. p. m. of potassium, when the solids were about twice as great. It is highly probable that these differences are due not alone to the variations in the potassium, but that some of the other ingredients were somewhat deficient when only about 225 p. p. m. of solids were present.

Attention should be directed to the failure of the relative transpiration figures to correspond even approximately with those of the green weights when marked variations occur in the amount of potassium carbonate. The average reduction in green weights, due to quartering the applications of potassium, was about 20 per cent., whereas the transpiration was reduced less than 2 per cent.

EXPERIMENT XXIV.

Wheat Grown from August 29 to September 14, 1906.

(Solids, about 450 p. p. m. of solution.)

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
64 p. p. m. of K in K_2CO_3....	228 275	6.95 7.54	251	7.24	100	100
64 p. p. m. of K in K_2CO_3, and 14 p. p. m. of Na in Na_2CO_3...	229 229	6.61 6.51	229	6.56	91	91
16 p. p. m. of K in K_2CO_3.....	206 239	5.38 5.82	223	5.60	89	77
16 p. p. m. of K in K_2CO_3, and 14 p. p. m. of Na in Na_2CO_3..	215 222	5.47 5.54	219	5.51	87	76
*About neutralized by HCl**						
16 p. p. m. K in K_2CO_3.....	235 212	5.66 5.24	223	5.45	89	75
16 p. p. m. of K in K_2CO_3... 14 p. p. m. of Na in Na_2CO_3..	229 200	6.00 5.40	215	5.70	86	79
Made slightly acid by HCl†						
16 p. p. m. of K in K_2CO_3...	230 230	5.84 5.46	230	5.65	92	78
16 p. p. m. of K in K_2CO_3, and 14 p. p. m. of Na in Na_2CO_3..	270 248	6.01 5.86	259	5.93	103	82

* The amount of acid added to each series was sufficient to make neutral, to methyl orange, the series containing only potassium.

† The amount of acid added to each series was sufficient to make the acidity in the series containing only potassium, equal to $\frac{N}{1500}$ by methyl orange, which was the indicator used in connection with this work.

The depression in the green weight, which appears in the foregoing table when the sodium carbonate was used to supplement 64 p. p. m. of potassium in potassium carbonate, did not occur in experiments XXII and XXIII when only a third as much sodium was used.

The addition of the small amounts of acid with 16 p. p. m. of potassium without sodium was practically without effect. When sodium carbonate supplemented the potassium, however, the alkalinity seems to have been sufficiently increased so that some possible advantage resulted from adding the hydrochloric acid; for the series to which no acid was added gave a relative green weight of 76; the one which was only slightly alkaline, because of the addition of a small amount of acid, gave 79; and the slightly acid series gave 82. These differences are small and simply served to suggest the advisability of the experiments which follow, in which different amounts of acid are used in connection with the alkaline carbonates.

EXPERIMENT XXV.

Wheat Grown from September 25 to October 8, 1906.

(Solids, about 450 p. p. m. of solution.)

Special Additions.	From Each Bottle.		Average. Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
16 p. p. m. K in K_2CO_3.....	111 114	3.91 4.16	112	4.03	100	100
16 p. p. m. K in K_2CO_3..... (Acidity made $\frac{N}{500}$ with HCl)	38 33	1.25 1.25	35	1.25	32	31
16 p. p. m. K in K_2CO_3..... (Acidity made $\frac{N}{278}$ with HCl)	32 27	.95 .92	30	.94	26	23
16 p. p. m. K in K_2CO_3, and 14 p. p. m. Na in Na_2CO_3... (Same amount HCl added as just above.)	37 23	1.19 .86	30	1.02	26	25
16 p. p. m. K in K_2CO_3..... (Acidity made $\frac{N}{200}$ with HCl)	26 30	.76 .84	28	.80	27	20

The above experiment shows little more than that the degree of acidity was too great, and caused so much injury to the plants that only an abnormal growth occurred. Preliminary to the following experiment, the young seedlings were allowed to grow for five days in a uniform nutrient solution containing 225 p. p. m. of solids.

EXPERIMENT XXVI.

Wheat Grown from October 1 to 15, 1906.

(Solids, about 450 p. p. m. of solution.)

Special Additions.	From Each Bottle.		Average Per Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
16 p. p. m. of K in K_2CO_3...	133 142	4.13 4.21	138	4.17	100	100
Neutralized with HCl						
16 p. p. m. of K in K_2CO_3...	136 152	4.38 4.58	140	4.48	101	107
16 p. p. m. of K in K_2CO_3, and 14 p. p. m. of Na in Na_2CO_3..	148 153	4.41 4.82	151	4.61	109	111
Acidity made $\frac{N}{500}$ with HCl						
16 p. p. m. of K in K_2CO_3...	53 52	2.61 2.66	52	2.63	38	63
16 p. p. m. of K in K_2CO_3, and 14 p. p. m. of Na in Na_2CO_3..	39 60	2.36 2.86	49	2.61	36	62
Acidity made $\frac{N}{275}$ with HCl						
16 p. p. m. of K in K_2CO_3...	45 44	2.12 2.14	44	2.13	32	51

An increase in green weight resulted above, when the solution containing potassium carbonate was made neutral with hydrochloric acid. With an acidity equal to $\frac{N}{500}$ and $\frac{N}{275}$ acid, however, the yield was again very much reduced, in spite of the fact that the seedlings were a little older when the experiment was begun.

EXPERIMENT XXVII.

Wheat Grown from October 1 to 15, 1906.

(Solids, about 450 p. p. m. of solution.)

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		AVERAGE PER BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
64 p. p. m. of K in K_2CO_3...	130 139	4.96 5.29	135	5.12	100	100
64 p. p. m. of K in K_2CO_3, and 14 p. p. m. of Na in Na_2CO_3.. (Enough HCl added to neutralize Na_2CO_3)	146 122	5.28 4.31	134	4.80	99	94
16 p. p. m. of K in K_2CO_3...	121 122	4.12 4.16	121	4.14	90	81
16 p. p. m. of K in K_2CO_3, and 14 p. p. m. of Na in Na_2CO_3...	114 120	3.94 3.92	117	3.92	87	77
Neutralized with HCl						
16 p. p. m. of K in K_2CO_3...	112 123	3.96 4.00	117	3.98	87	78
16 p. p. m. of K in K_2CO_3, and 14 p. p. m. of Na in Na_2CO_3..	111 134	3.88 4.44	123	4.16	91	81
Acidity made $\frac{N}{500}$ with HCl						
16 p. p. m. of K in K_2CO_3.....	25 31	1.39 1.61	28	1.50	20	29
16 p. p. m. of K in K_2CO_3, and 14 p. p. m. of Na in Na_2CO_3.	16 20	1.58 1.25	18	1.41	13	28
Acidity made $\frac{N}{278}$ with HCl						
16 p. p. m. of K in K_2CO_3...	24 33	.95 .97	29	.96	21	19
16 p. p. m. of K in K_2CO_3, and 14 p. p. m. of Na in Na_2CO_3..	26 8	.96 .93	17	.94	12	18

In the three preceding experiments, an opportunity is afforded for comparing the growth in a solution containing 16 p. p. m. of potassium in carbonate, and in the same solution after the addition of hydrochloric acid, in order to create an acidity to methyl orange of $\frac{N}{300}$ and $\frac{N}{275}$. In experiments XXV and XXVII, wherein the young seedlings were placed at once in the nutrient media, the solution with an acidity of $\frac{N}{300}$ gave a depression in green weight equal to 69 and 64 per cent., respectively, in the two experiments, and an increase in the acidity to $\frac{N}{275}$, caused a total reduction of 77 per cent. in both cases. In experiment XXVI, wherein the seedlings were allowed to grow for five days in a uniform nutrient solution before they were placed in the special solutions, the green weight was depressed only 37 and 49 per cent. by the two solutions with different degrees of acidity. Although these amounts of acidity were found to be so great that no light was thrown upon the question of whether the solutions containing the alkali carbonates could be advantageously affected by the addition of acid, they are, nevertheless, of some value in showing the degree of toxicity to wheat seedlings, of acid in nutrient solutions, and are recorded for this reason.*

The following experiment was conducted in the glass-house, later, to ascertain whether the beneficial effect produced by sodium chlorid and sulfate, in connection with 4 or 8 p. p. m. of potassium, would be shown by sodium carbonate; and to secure, incidentally, a few more data upon the question of whether the alkalinity of the solutions, under the conditions of these experiments, is a matter of any importance.

* See also Cameron and Breazeale, Jour. Phys. Chem. 8, 1 (1904).

EXPERIMENT XXVIII.

Wheat Grown from February 18 *to March* 7, 1907.

(Solids, about 450 p p. m. of solution.)

SPECIAL ADDITIONS.*	FROM EACH BOTTLE.		AVERAGE PER BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.	Transpiration.	Green weight.
64 p. p. m. of K in K_2CO_3...	241 219	6.26 5.77	230	6.02	100	100
8 p. p. m. of K in K_2CO_3...	152 171	3.61 3.66	162	3.64	70	60
8 p. p. m. of K in K_2CO_3, and 14 p. p. m. of Na in Na_2CO_3..	170 166	4.08 3.84	168	3.96	73	66
8 p. p. m. of K in K_2CO_3,. 14 p. p. m. of Na in Na_2CO_3. and H_2SO_4 equiv. to the Na and half the K.	185 202	4.34 4.32	194	4.33	84	72
8 p. p. m. of K in K_2CO_3... 14 p. p. m. of Na in Na_2CO_3, and HCl equiv. to the Na and half the K.	181 191	4.06 4.32	186	4.19	81	70

* The Mg was supplied in 10 p. p. m. of $MgCl_2$, and 36 p. p. m. of Mg_2SO_4, so that all of the series would contain Cl and S.

It may be seen that the addition of sodium carbonate to 8 p. p. m. of potassium, increased the relative green weight from 60 to 66; and that when the sulfuric acid was also added, the relative weight became 72; similarly, with hydrochloric acid, it was 70. The transpirations were likewise increased by the addition of the acids. These and earlier results seem to indicate that under certain circumstances the increase in alkalinity due to the addition of even 14 p. p. m. of sodium in carbonate may be advantageously offset by the addition of acid. Under other circumstances, however, such small amounts of carbonates have failed to alter the reaction of the solutions sufficiently to influence growth.

In connection with the growth of wheat seedlings in paraffined wire baskets, attention has been called to the fact that the amount of transpiration relative to the green weight was lessened by the application of muriate of potash, although the particular sources of nitrogen and phosphoric acid did not with certainty produce the same effect.* The experiments in solution, which have been recorded in the preceding pages, show that the increase in green weight, due to an abundance of potassium as compared with a deficiency, was almost always greater than the increase in transpiration, and that the increase caused by the addition of sodium to a deficient amount of potassium was likewise greater in green weight than in transpiration. These differences were especially marked in the case of the carbonates, when the alkalinity of the nutrient solutions was greater. Sachs and Burgerstein found that certain plants transpired less in water containing alkali and more in acidulated water than in distilled water.†

According to Pfeffer,‡ it appears from Burgerstein's papers "that the effect which a salt may exercise upon transpiration when added to a nutrient solution in which a plant is growing, may be different to that produced when a similar quantity of the same salt is offered to another plant cultivated in distilled water." In the experiments

* R. I. Agr. Expt. Sta., Bul. 120. p. 136.

† Vines, Physiology of Plants, 1886, p. 110–111.

‡ Physiology of Plants, Ewart's trans., 1900, p. 249.

conducted in the manner described in the present paper, an increase in growth in one series over another, gives rise to less depth of nutrient solution, due to the larger amount of water transpired, and consequently there is a larger exposed surface of the roots. This may have retarded the transpiration to some extent, but even in those cases where the supply of potassium was sufficiently great so that the addition of sodium resulted in no increased growth, and therefore, no greater removal of solution, the transpiration was depressed when the sodium was added. When a deficient amount of potassium was supplemented by extra calcium, however, instead of by sodium, in which case no increase in growth usually resulted, the relative transpiration did not seem to be affected to any extent; which was the case also in those instances when the phosphorus, nitrogen, and magnesium were increased. It should be recognized that under the conditions of these experiments the optimum amounts were not usually exceeded, and that the variations in the concentrations of the solutions were within comparatively narrow limits. The object in securing the transpiration was to enable a better comparison of the series during the period of growth, rather than to study the specific effect of the different salts on the amount of water transpired, but the indications seem worthy of incidental mention.

The principal question under consideration in connection with the experiments recorded in the present paper has been as to whether or not sodium causes an increase in the growth of wheat seedlings. There seems no escape from the conclusion that it did when potassium was sufficiently lacking. The amount of the increase depended to a considerable degree upon the extent of the deficiency of potassium, as measured by a comparison of the growth in a solution containing an optimum amount of potassium, with one containing much less. As a rule, under favorable growing conditions, a reduction from 32 p. p. m. of potassium in one series to 8 p. p. m., in another, caused a depression in growth which it seemed undesirable to exceed for fear of disturbing the normal functions of the plant, although quite frequently still less potassium was furnished. Under such circum-

stances, the growth is of course largely dependent upon the frequency of the renewal of the solutions, and upon the climatic conditions.

The following table summarizes those results from the various experiments which show the relation between the series receiving 32 p. p. m. of potassium and those receiving only 8 p. p. m., and also between the latter and those receiving sodium in addition to the 8 p. p. m. of potassium. The solids equalled about 450 p. p. m. in each case. In a number of instances, which have not been included in the table, the amount of potassium was reduced to 4 p. p. m., with a consequent greater reduction in growth, and a greater benefit when supplemented by sodium.

The Percentage Change in the Green Weight of Wheat Seedlings Caused by Withholding a part of the Potassium, and again by Substituting Sodium for the Same.

No. and Date of Experiment.	Potash and Soda Salts used.	Depression in green weight by reducing K from 32 to 8 p. p. m.	Increase in green weight by adding Na to 8 p.p.m. of K.
		Per cent.	Per cent.
I..Apr. 26–May 19......	K Cl, Na Cl........	33	16
II..May 16–June 7.......	K Cl, Na Cl........	14	3
V..May 25–June 12......	K Cl, Na_2SO_4......	40	30
VI..June 29–July 14.....	K Cl, Na_2SO_4......	35	15
VII..Aug. 16–31..........	K Cl, Na_2SO_4......	33	19
VIII..July 11–27..........	K Cl, Na_2SO_4......	42	26
IX..July 17–Aug 1.......	K Cl, Na_2SO_4......	35	20
XIV..Sept. 10–24..........	K Cl, Na_2SO_4......	29	4
XVII..Sept. 15–Oct 1.......	K Cl, Na_2SO_4......	32	4
XVIII..Sept. 25–Oct. 11.....	K Cl, Na_2SO_4......	..	9
XIX..Nov. 30–Dec. 21	K Cl, Na_2SO_4......	26	1
XX..Jan. 23–Feb 9........	K Cl, Na_2SO_4	34	11
XXI..Feb. 11–Feb. 27......	K Cl, Na_2SO_4......	27	14
X..July 5–20............	K_2SO_4, Na_2SO_4....	25	9
XI..July 27–Aug. 8.......	K_2SO_4, Na_2SO_4....	27	12
XXVII..Feb. 18–Mar. 7.......	K_2CO_3, Na_2CO_3....	--	10

It may be seen from the above table that, as a rule, whenever the depression in green weight caused by reducing the potassium from 32 to 8 p. p. m. was around 30 per cent., the addition of sodium resulted in a gain of 10 per cent., or more. It will be noticed, how-

ever, in experiments XIV, XVII, and XIX, that although this amount of depression was brought about by withholding a part of the potassium, the increase caused by the sodium was very small. These three experiments were conducted in the fall of the year, the first two in the summer glass-house, and the last, in the chemical laboratory, where assimilation was inactive, and it seems not improbable that sodium may be most beneficial as a partial substitute for potassium, under conditions favoring active photosynthesis. It should be stated that the solutions were not changed at constant intervals during the various experiments; the rapidity of growth and demands of the plant for potassium as a rule determining the length of the intervals. The exact quantitative effect of a given nutrient solution would, of course, require a detailed consideration of this and many other factors which it would be unwise to give at this time.

In connection with certain of the experiments which have been described previously, the amounts of potassium left in the solutions after the seedlings had grown in them for one or more days, were determined by the colorimetric method.* The object was to secure a measure of the deficiency of potassium, other than that furnished by the growth and transpiration of the plants. It was found usually that 8 and 4 p. p. m. of potassium were nearly all removed from the nutrient solution at the end of the first day's growth, so that during a three-day period, the plants had very little potassium in their nutrient solution for the last two days of the period, with the result that the growth was considerably depressed. It was under such conditions that the addition of sodium became decidedly beneficial. The determinations of the potassium made it possible also to study the influence of sodium on the absorption of potassium by the plant.

The determinations are shown in the following table:

* Bureau of Soils, U. S. Dept. of Agr., Bul. 31 (1906) p. 31.

The Amount of Potassium, in Parts per Million of the Nutrient Solutions, left in the Various Series by Wheat Seedlings Grown During Different Periods.

Experiments and Periods.	Rations of Potassium, Sodium, and Extra Calcium.								
	1 K.	1 K+1 Na.	1 K+1 Ca.	½ K.	½ K+½ Na.	½ K+½ Ca.	¼ K.	¼ K+¼ Na.	¼ K+¼ Ca.
1906.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.
Experiment I.									
May 12	.4	...	...	.3	.5	.5	T*	.6	.4
May 13–16	.7	...	...	.7	.8	T	T	.8	T
May 17–19	T	...	...	T	.4	T	T	.6	T
Experiment II.									
May 13–15	T	...	...	T	.5	T	...	...	...
May 19–21	T	...	...	T	.4	T	T	.3	...
May 22–25	T	...	...	T	.6	T	...	...	...
May 26	5.2	...	...	T	.4	T	T	.3	T
Experiment V.									
(Seeds removed).									
June 8–9	.5	2.0	.5	T	...	...	...	...	...
June 10–11	T	.5	T	T	...	...	...	...	...
June 12	T	1.2	T	T	.3	T	...	...	...
(Seeds not removed.)									
June 8–9	.3	.5	T	T	...	...	...	...	...
June 10–11	T	.5	T	...	...	...	...	...	...
June 12	T	1.2	T	T	.5	T	...	...	...

*Trace.

The Amount of Potassium, in Parts per Million of the Nutrient Solutions, left in the Various Series by Wheat Seedling Grown During Different Periods.—Continued.

EXPERIMENTS, AND PERIODS.	RATIONS OF POTASSIUM, SODIUM, AND EXTRA CALCIUM.								
	1 K.	1 K + 1 Na.	1 K + 1 Ca.	$\frac{1}{2}$ K.	$\frac{1}{2}$ K + $\frac{1}{2}$ Na.	$\frac{1}{2}$ K + $\frac{1}{2}$ Ca.	$\frac{1}{8}$ K.	$\frac{1}{8}$ K + $\frac{7}{8}$ Na.	$\frac{1}{8}$ K + $\frac{7}{8}$ Ca.
1906.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.
Experiment VI.									
(Seeds removed).									
July 8–9	....	....	....	.8	1.2	T*	....	....	....
July 10	....	....	....	.0	.8	....	....	....	....
July 11	....	....	....	T	1.0	T	....	....	....
July 12	....	....	....	.8	.9	.5	....	....	....
(Seeds not removed).									
July 8–9	1.6	2.6	3.3	.6	1.6	.5	....	....	....
July 10	4.2	3.1	5.3	0.0	T	....	....	....	....
July 12	3.8	4.9	7.8	.5	1.0	T	....	....	....
July 12	6.0	10.8	9.4	T	.5	.7	....	....	....
Experiment XIV.									
Aug. 25–26	T	2.0	1.2	T	.7	.6	....	....	....
Aug. 27	5.7	7.3	7.6	T	.8	1.1	....	....	....
Aug. 28	1.5	8.0	5.7	T	.8	.8	....	....	....

* Trace.

In the foregoing table the full ration of potassium (1 K) usually equals 32 p. p. m., the fourth and eighth rations, of course, equalling 8 and 4 p. p. m. of potassium, respectively.

The amount of potassium removed from a solution depends upon the size of the plants, the length of the period, and the rapidity of growth, as well as upon the associated nutrients. The latter factor is the one which it is desired primarily to emphasize in this connection. It should be borne in mind that in general the addition of neither sodium nor extra calcium to the full ration of potassium, increased the crop. Again, a reduction of potassium to 8 and 4 p. p. m. depressed the yield 30 to 40 per cent., and yet when sodium supplemented these deficient amounts of potassium, an increase of from 10 to 25 per cent. usually occurred, whereas, extra calcium did not, as a rule, cause an increase.

In view of the larger plants which resulted when sodium supplemented quarter and eighth rations of potassium, it is noteworthy that, without exception, the amount of potassium remaining unused by the plant should be greater than when the small amounts of potassium were used alone, and, with few exceptions, than when the extra calcium was added. This observation is interesting in connection with the results secured at the Rhode Island Station by the analyses of crops grown in the field in connection with different relative amounts of potassium and sodium, and recorded in the preceding annual report. It was shown there that crops grown in plats which received a quarter ration of potassium, almost invariably contained a higher percentage of sodium and a lower percentage of potassium when a full ration of sodium was applied in addition than when a quarter ration only was present. The yields were larger when the extra sodium was present.

In the solution experiments it was desired at the outset that the small amounts of potassium should be used so promptly, that during a portion of each period, the plants would be practically without any of this element, in order to see if sodium was of any advantage under such circumstances. This explains why determinations were at-

tempted when very frequently only a trace of potassium was present.

The fact that the addition of sodium to a limited amount of potassium resulted in a larger yield and the removal of a smaller amount of potassium, proves that there is a much more economical use of the potassium when sodium is present. The figures show that a determinable amount was left in the solutions which were supplemented by sodium, even after all but a trace had been removed from the solution to which potassium alone was supplied. In other words, a limited amount of potassium lasted for a longer time when sodium was present. The same seems to be true, also, as a rule, when as much as 32 p. p. m. of potassium were supplied. In experiments VI and XIV, the determinations were made after such short periods that a determinable amount of potassium remained unabsorbed by the plants when 32 p. p. m. were used alone and in connection with sodium or with extra calcium. The least amount of potassium remained in the solutions when this element was not supplemented by either sodium or extra calcium, but in these particular instances there was frequently as much potassium conserved by the calcium as by the sodium. When it is considered, however, that in experiment VI the relative green weights at the close were respectively 100, 109, and 97, with full potassium alone, and supplemented in turn by sodium and calcium, it will be seen that some allowance should be made for the extra size of the plants when sodium was present. In experiment XIV, however, no such allowance is required.

In a few of the experiments, potassium determinations were not only made in the different nutrient solutions, as recorded in the preceding table, but in the solution remaining after the same plants, which had been growing in the different nutrient solutions, had been allowed to grow for a day in a uniform nutrient solution in which a full ration of potassium (32 p. p. m.), but neither sodium nor extra calcium was present.

The determinations are recorded below:

The amount of residual potassium in parts per million of the originally uniform nutrient solution in which wheat seedlings from different series had been allowed to grow.

Experiments, and Periods.	Rations of Potassium, Sodium, and Extra Calcium in the Solutions from which the Plants had been Transferred to a Uniform Solution.					
	1 K.	1 K+1 Na.	1 K+1 Ca.	½ K.	½ K+½ Na.	½ K+½ Ca.
	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K, p. p. m.	K. p. p. m.
Experiment IV p. 305.						
June 7............	14.	....	....	6.4	11.6	12.4
Experiment VI p. 309.						
(Seeds removed).						
July 13..........	....	....	....	3.2	3.6	6.8
July 14..........	....	....	....	.9	.5	1.1
(Seeds not removed).						
July 13...........	3.3	1.9	4.0	1.	.0	T
July 14...........	T	.0	T	.0	.0	.0
*Experiment XIV p.*319.						
Aug. 29...........	6.9	8.0	5.9	1.0	1.2	1.8
Aug. 30...........	7.4	7.9	9.8	2.9	3.6	4.7
Aug. 31...........	1.2	2.0	4.0	4.0	1.5	2.2

According to the above table, the three series of plants which had been grown during the first period, with a full ration of potassium, without and with sodium or calcium, as a special addition, left varying relative amounts of potassium when grown upon different days in the uniform nutrient solution, so that positive generalizations regarding the effect of the sodium and extra calcium upon the absorption, are not justified with so few results. Experiment XIV, however, in which the green weights of the three series were practically the same, shows that slightly less potassium was consumed by the plants which had previously received the full ration of potassium, supplemented by sodium, than in the other two instances. If the three days' observations be taken collectively and the average

amount of removed potassium, in parts per million of solution, be calculated for every ten grams of transpired water, it will be found that 4.6 p. p. m. were removed in the first series, which received full potassium, and even a little more, namely 4.9 p. p. m., when the potassium had originally been supplemented by sodium. In this same experiment, similar calculations in connection with the plants which originally received only 8 p. p. m. of potassium show that, for ten grams of transpiration, the amount of potassium removed from the uniform nutrient solution was 7.8 p. p. m. when no sodium had ever been present, and 6.4 p. p. m. in the series to which sodium had originally been added. Experiment VI (seeds removed) afforded another opportunity for similar calculations for two days' observations in connection with plants originally receiving a quarter ration of potassium, and it is found that 7.6 p. p. m. were removed when sodium had been absent, and 7.2 p. p. m. when it had been present, originally. Similarly in experiment IV the amounts expressed in the same order, were 8.2 and 6.0 p. p. m. It appears from the above considerations, that the plants which grew originally in solutions containing a somewhat deficient amount of potassium, not only removed less of this element when it was supplemented by sodium, but that the same plants when transferred to a uniform nutrient solution containing an abundance of potassium, but no sodium, again seemed inclined to absorb less potassium in the series to which sodium had been originally added. Breazeale,* as a result of similar determinations, found that in three different experiments when no sodium had been added during the first period, 4.36, 5.67, and 4.00 p. p. m. of potassium had been removed from a uniform nutrient solution per ten grams of transpiration, whereas, only 2.06, 0.65, and 2.30 p. p. m. had been removed by the wheat plants, which had been supplied with sodium as well as potassium during the first period of growth. He made no attempt to have the potassium somewhat deficient during the first period of growth, as in certain of our series, and, furthermore, the seeds were removed from the young seedlings. It will be seen,

* Jour. Am. Chem. Soc., 28, 1019–1021, (1906.)

however, that in no case did our results indicate, in such a marked degree as those of Breazeale, that sodium exerted an effect upon the absorption of potassium.

SAND CULTURE EXPERIMENT WITH CHUL WHEAT.

The sand for the experiment was white crushed quartz and had the appearance of being pure. It was prepared by digesting in warm sulfuric acid and subsequently washing with water, and roasting. The experiment was conducted according to the wire-basket method.*

The twenty baskets or pots which were used, each contained 350 grams of the sand, and were divided into four groups of five baskets each. Chemically pure calcium nitrate, magnesium sulfate, mono-calcium phosphate and ferric nitrate were added alike to each pot. The object of the experiment was to compare the results secured with an optimum amount of potassium, a deficient amount of potassium, and the latter supplemented by sodium, and again by extra calcium. The nutrients were added in solution from time to time during the progress of the experiment. Each basket received during the experiment .369 gram of calcium nitrate, .141 gram of magnesium sulfate, .094 gram of mono-calcium phosphate, and a small amount of ferric nitrate. In addition to these salts, baskets Nos. 1 to 5 each received the full ration of potassium sulfate, .131 gram; Nos. 6 to 10, about one-fourth of the above amount of potassium sulfate or .032 gram (referred to as a quarter ration); Nos. 11 to 15, the quarter ration of potassium, and .056 gram of sodium sulfate; and Nos. 16 to 20, the quarter ration of potassium, and .056 gram of calcium sulfate. The above amounts refer to the anhydrous salts.

The wheat was planted August 13, 1906, the baskets were sealed August 20, and the experiment was discontinued August 31.

The transpiration from August 20 to August 31, and the green weights of that portion of the young plants which was above the sand, are given in the following table in grams:

* Bureau of Soils, U. S. Dept. Agr., Bul. 23, and Circ. 18.

Special Additions.	Basket No.	Per Basket. Transpiration.	Per Basket. Green weight.	Total. Transpiration.	Total. Green weight.	Relative. Transpiration.	Relative. Green weight.
Full ration of potassium....	1	122	2.21				
	2	124	2.39				
	3	125	2.26	653	12.20	100	100
	4	130	2.49				
	5	152	2.85				
Quarter ration of potassium.	6	111	1.83				
	7	99	1.73				
	8	100	1.86	510	8.78	78	72
	9	102	1.76				
	10	98	1.60				
Quarter ration of potassium, plus sodium.............	11	141	2.51				
	12	118	2.11				
	13	126	2.14	610	10.68	93	88
	14	101	1.80				
	15	124	2.12				
Quarter ration of potassium, plus extra calcium.......	16	109	1.81				
	17	130	2.28				
	18	101	1.70	592	10.31	91	85
	19	135	2.55				
	20	117	1.97				

The above table exhibits results which agree with those obtained by water culture as far as the beneficial effect of sodium in connection with a deficient amount of potassium is concerned. Calcium sulfate, however, gave practically the same average increase as sodium sulfate when used to supplement the quarter ration of potassium, although it failed to do so in the water cultures.

In the water-culture experiments there is, of course, no question but that the nutrients are all available, whereas, in sand culture, although the nutrients may be added in solution, there is a question as to how much may be held chemically or physically by the sand.

The effect of a substance in the case of sand cultures may be in part due, therefore, to an influence upon the power of the sand to retain certain ingredients of plant food. It is not surprising then that the calcium sulfate exerted a beneficial effect in the sand culture which it failed to exert in the water cultures.

SAND CULTURE WITH RADISHES.

This experiment was conducted in the same kinds of sand and baskets as were used in the preceding wheat experiment, and the general scheme of conducting the test was the same. The radish seeds were planted on August 4, 1906. It became evident quite early in the experiment that the plants which received calcium sulfate as a supplement to the quarter ration of potassium were the poorest, even falling slightly behind those receiving the quarter ration of potassium, but no calcium sulfate. The quarter ration of potassium produced much poorer plants than the full ration, but when the smaller quantity of potassium was supplemented by a three-quarter ration of sodium, the growth appeared nearly equal to that with the full potassium. An idea of the growth may be obtained from the accompanying figure (Fig. 2), which shows one representative basket from each group of five, and illustrates the condition on August 30, 1906.

The plants which received a quarter ration of potassium alone, and supplemented by calcium sulfate, finally failed to grow and were allowed to drop out of the experiment. The two groups which received full potassium, and quarter potassium plus sodium, continued to make a slow growth till October 4, when the experiment was discontinued. Only a few plants had begun to form radishes. The upper leaves had remained green, but the lower ones had become dry and were dropping in many cases.

SUMMARY.

This paper gives the results of growing wheat seedlings in complete nutrient solutions containing deficient, and approximately optimum

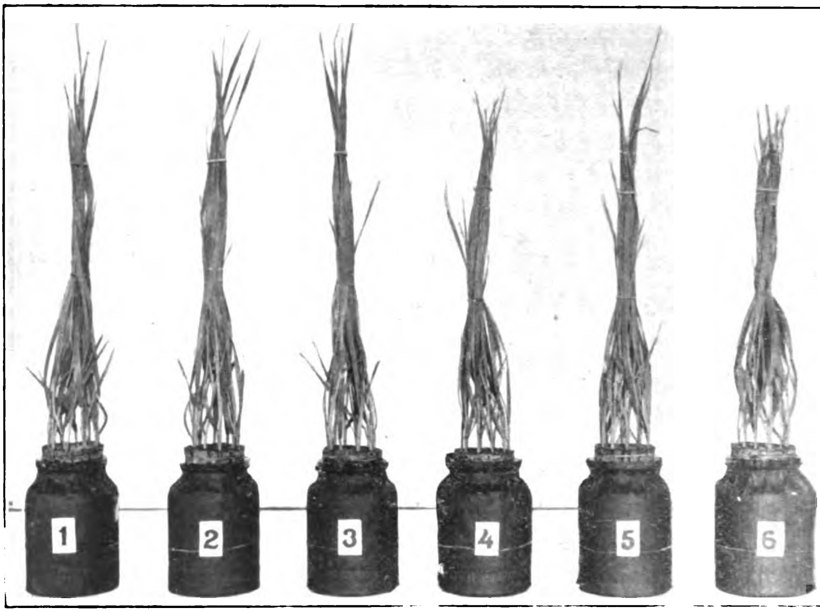


FIG. 1.—WHEAT SEEDLINGS.

One bottle from each Series of Experiment VIII.

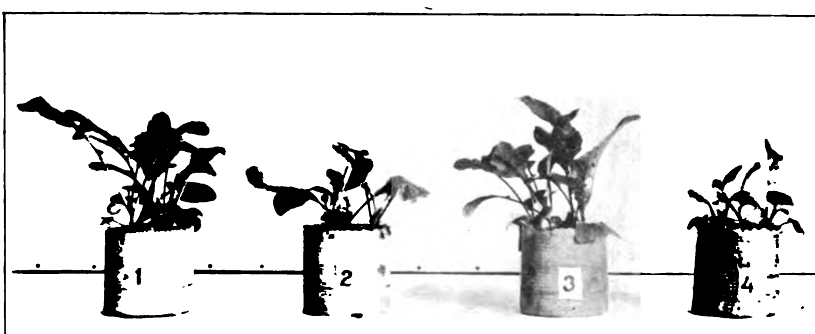


FIG. 2.—RADISHES.

Full Potassium.	Quarter Potassium.	Quarter Potassium, plus Sodium.	Quarter Potassium plus extra Calcium.

amounts of potassium, and the same supplemented by sodium and again by extra calcium.

Sodium seemed to cause no increase in growth when an optimum amount of potassium was present, but when the deficiency of potassium was great enough to cause about a 30 per cent. depression in the green weight produced, the addition of sodium did give an increase in growth which usually amounted to 10 per cent., or more, within a period of from two to three weeks, under the particular conditions of these experiments.

The extra calcium did not on the whole increase the growth, either when used with an optimum or a deficient amount of potassium.

The beneficial effect of sodium, when accompanying a small amount of potassium, is not attributed to the increase in the osmotic pressure of the solution, because the addition of extra calcium, magnesium, phosphorus, or nitrogen failed to cause an increase in growth.

The increase in transpiration was usually less than that in green weight, when sodium was added, or the potassium increased. This seemed especially marked with the alkali carbonates.

A larger amount of potassium was left in the solution by the growing seedlings when the potassium in the nutrient medium was supplemented by sodium. In other words, sodium was a conserver of potassium.

In two experiments by the paraffined wire basket method, with white quartz sand which had been digested with acid, sodium, when supplementing a deficient amount of potassium, affected the growth similarly as in the solution experiments.

THE RELATION BETWEEN THE EFFECTS OF LIMING, AND OF NUTRIENT SOLUTIONS CONTAINING DIFFERENT AMOUNTS OF ACID, UPON THE GROWTH OF CERTAIN CEREALS.

BURT L. HARTWELL AND F. R. PEMBER.

The study, by field experiments at this Station, of the relative effect of lime on the growth of a large variety of plants during a number of seasons, has emphasized the remarkable differences exhibited by plants in their response to liming; the growth of some varieties having been considerably depressed by the application of lime, while with others, growth was absolutely impossible unless alkaline material was first added to the soil. The fact that other alkaline substances, such as sodium and potassium carbonates, magnesium oxid, and magnesium carbonate produced results similar to the lime, with such plants as were subjected to their action, led naturally to the thought that the beneficial results from liming certain of our soils might be due largely to the neutralization of a detrimental degree of acidity.

If soil acidity, regardless of the possible presence of poisonous compounds accompanying it, were the direct cause of the failure of certain plants to make a normal growth, it seemed as though these same plants would be injured to a much greater extent when grown in nutrient solutions to which definite amounts of acid had been added, than would those which were not benefited by applications of lime; and it was the purpose of the work herein recorded to ascertain if the effect of different degrees of alkalinity and acidity

in nutrient solutions, would exhibit any similarity to the field observations.

A limited attempt was made at first, to grow certain plants in solution, which had exhibited very wide differences as to the effect of lime upon them. Lupine was selected as a crop which, according to the effect of liming upon it, might be expected to resist the action of acids; and from the same standpoint, alfalfa and vetch might prove relatively less resistant. It was soon evident that unless a large number of lupine seedlings were included in the experiment, the wide differences between individual plants would render the results from different treatments of little value, and the slow growth of the alfalfa and vetch seedlings was an objection to their use. A preliminary period of nursing, in a uniform nutrient solution, seemed to be required before the true vigor of the seedlings could be determined; and inasmuch as it was desired to ascertain the effect of the reaction of the solution on the growth of the seedlings in the first few weeks, the apparent difficulties in connection with the employment of the plants named above, led to the use of the cereal seedlings, and to the method which is described in the preceding paper (page 300).

The relative effect, on the growth of certain cereals, of applying slaked lime to the soil may be judged from the following table of field results.*

TABLE I.—*Percentage Increase in the Weight of Mature Plants, Due to the Application of Lime.*

	1893	1894	1895	1896	1899
Rye....................	13	3	(-) 25	38	20
Oats....................	26	9	7	...	26
Wheat..................	..	...	91	...	55
Barley..................	80	106	258	156	195

The above percentage gains were derived from the results obtained from the permanent plats Nos. 27 and 29. Only very small areas

* R. I. Agr. Exp. Sta. Bul. 46, and Ann. Rpt. 13.

were usually occupied by a given plant and the exact amount of the gain is, therefore, of much less significance than the fact that the order of arrangement of the four cereals was the same for each year, from the standpoint of the relative effect of liming upon their growth.* It will be noticed that there is a very wide difference between the two extremes, rye and barley. In 1893, 5,400 pounds per acre of air-slaked lime were added, and in 1894, 1,000 pounds; but in the subsequent years no further applications of lime were made.

The article which precedes this, contains, incidentally, a few data concerning the effect upon wheat seedlings of hydrochloric acid, in a nutrient solution containing potassium carbonate as a source of potassium. It was shown that when the seedlings were placed in a $\frac{N}{500}$ acid solution at once, there was a depression in growth, in two experiments, of 69 and 64 per cent. as compared with the growth in the non-acidulated solution; and when the acidity, also to methyl orange, was $\frac{N}{375}$, there was a depression of 77 per cent. In a third experiment, in which the seedlings were first grown for five days in a neutral nutrient solution, to increase their powers of resistance, the depression in growth in the $\frac{N}{500}$ and $\frac{N}{375}$ solutions was 37 and 49 per cent., respectively. The acidity in the above instances was so great that it interfered too seriously with the growth of the seedlings, and less acid was used in the work which will now be described.

Each of the first three experiments included three different nutrient solutions, in order to determine whether the specific effect of an added acid or alkali would vary materially with different nutrient solutions which were practically neutral. The solutions will be designated by the Roman numerals, I, II, and III. Solution I, Knop's, contained the following per liter: 30 cc. $\frac{N}{10}$ calcium nitrate, 8 cc. $\frac{N}{10}$ potassium nitrate, 8cc. $\frac{N}{10}$ di-potassium phosphate, and 8 cc. $\frac{N}{5}$ magnesium sulfate. Solution II contained per liter, 30 cc. $\frac{N}{10}$ calcium nitrate, 8 cc. $\frac{N}{10}$ potassium chlorid, 8 cc. $\frac{N}{10}$ mono-calcium phosphate, and 8 cc. $\frac{N}{5}$ magnesium sulfate. Solution III con-

* In experiments by Voelcker at Woburn, England, with a mixture of ammonium sulfate and ammonium chlorid it was found that oats were injured less than wheat. and wheat less than barley. Jour. Royal Agr. Soc., England, 62, p. 286 (1901).

tained, per liter, 20 cc. $\frac{N}{10}$ calcium nitrate, 11 cc. $\frac{N}{10}$ potassium nitrate, 8 cc. $\frac{N}{10}$ mono-sodium phosphate, 8 cc. $\frac{N}{10}$ sodium chlorid, and 16 cc. $\frac{N}{5}$ magnesium sulfate. A small amount of a soluble ferric salt was added to each solution. No attempt was made to have the different solutions contain even the principal nutrients in equal amounts, but these were believed to be sufficiently abundant for maximum growth. The total solids, although not the same in all of the solutions, equalled not far from 500 parts per million of solution. Solution III was different from the others in that the amount of magnesium was increased so that it was about equal to the calcium, and in being the only one which contained sodium.

The data in the following tables are not presented with the object of comparing the different nutrient solutions, but rather to show the effect in each case of the added alkali and acid upon the growth of seedlings; therefore, the "relative" transpirations and green weights, in case of a given nutrient solution, are based upon a comparison in which the "neutral" solution, unaccompanied by acid or alkali, is taken as 100; and the relation of the three nutrient solutions is purposely not made prominent.

The nutrient solutions themselves were practically neutral, being slightly acid to phenolphthalein and slightly alkaline to methyl orange, and the normality of the modified solutions, before the plants had grown in them, was calculated as a rule from the strength of the added alkali and acid, and was not determined by titration.

TABLE II.—*Transpiration and Green Weight, in Grams, of Chul Wheat Seedlings Grown in Solutions with Different Reactions.*

Nutrient Solutions. Reaction.	No.	Transpiration, per bottle, 10 plants.	Green weight, per bottle, 10 plants.	Relative transpiration, 20 plants.	Relative green weight 20 plants.
Neutral	I	211 202	5.2 5.5	100	100
	II	197 289	5.1 6.3	100	100
	III	225 215	5.8 5.3	100	100
Alkaline, $\frac{N}{625}$, by sodium hydroxid	I	204 214	5.0 5.4	101	97
	II	228 196	5.7 5.0	87	93
	III	150 195	4.2 5.1	71	84
Acid, $\frac{N}{1667}$, by hydrochloric acid	I	62 90	1.9 3.7	37	52
	II	110 62	3.5 2.7	35	54
	III	93 63	3.7 1.5	35	47

The data given in the preceding table were obtained from an experiment conducted between December 19, 1906 and January 5, 1907, under unfavorable conditions of light and heat, which may explain the rather wide differences which occasionally occurred between the results from parallel bottles.

From an inspection of the results from the individual bottles one would hardly be justified in saying that there was any depression in growth whatever, caused by the addition of the sodium hydroxid,

except with solution III, in which case both bottles containing the alkaline solution were accompanied by less transpiration and green weight than either of those containing the neutral solution.

The acid caused a depression of about 50 per cent. in green weight and of about 65 per cent. in transpiration, with all three solutions. The greater relative depression in transpiration than in green weight should be noticed.

The plants were so seriously affected by the $\frac{N}{1667}$ acid solution, that in the following experiment with barley, the acidity was reduced one-half. The test with the barley was conducted between December 26, 1906, and January 18, 1907, in the same kind of nutrient solutions and under similar, somewhat unfavorable conditions.

Table III—Transpiration and Green Weight, in Grams, of Barley Seedlings Grown in Solutions with Different Reactions.

Nutrient Solutions. Reaction.	No.	Transpiration, per bottle, 10 plants.	Green weight per bottle, 10 plants.	Relative transpiration, 20 plants.	Relative green weight, 20 plants.	Alkalinity.*
Neutral.........	I	234 194	7.6 6.4	100	100	4.2
	II	241 241	7.6 7.7	100	100	4.0
	III	215 193	8.0 6.9	100	100	3.8
Alkaline, $\frac{N}{625}$, by sodium hydroxid......	I	260 263	8.4 8.0	122	117	11.1
	II	203 230	7.2 7.4	90	90	10.0
	III	204 203	7.0 7.4	100	100	10.7
Acid, $\frac{N}{8854}$, by hydrochloric acid	I	170 184	6.2 6.7	83	92	2.0
	II	210 184	6.7 6.0	82	83	1.8
	III	189 175	6.7 6.4	84	89	2.0

The preceding table shows an unmistakable depression in growth when the acid was added. The sodium hydroxid seemed to cause considerable gain in the case of solution I, whereas, in the preceding experiment, with wheat, there was a depression in one case, although with a different nutrient solution from the one here affected. A

* Average number of cc. of $\frac{N}{100}$ sulfuric acid required, after the last five days' growth of the plants, to make neutral to methyl orange 50 cc. of the nutrient solution which had been made up to the original volume. Ten cc. is equivalent to $\frac{N}{500}$.

greater degree of alkalinity could hardly have been used at the outset, in these experiments, without danger of causing a precipitation in the nutrient solutions. Nevertheless, taken as a whole, the growth was not seriously affected by the alkali, although the titrations show that, with methyl orange as an indicator, an alkalinity equal to $\frac{N}{100}$ and greater, was reached after the last five days' growth of the seedlings; even though water had been added to replace that removed by transpiration, before the alkalinity was determined. In connection with some of the work recorded in the preceding article, where the carbonates of potassium and sodium were used in the nutrient solution, and special precautions were taken to add the nutrients in such a way as to prevent the formation of a precipitate, the alkalinity was frequently greater at the end of a period of growth than that recorded in the present connection, and yet no constant positive benefit resulted from reducing the alkalinity by the addition of acid. It is evident, therefore, that the growth of wheat and barley seedlings is not very much affected by any degree of alkalinity which is less than would cause a precipitation in an ordinary nutrient solution, and in the following work, attention was, therefore, directed only to the effect of acids.

In the following table are presented the results of an experiment conducted between January 29 and February 13, 1907, with the object of ascertaining the least concentration of acid which would exert an appreciable effect upon the growth of wheat seedlings.

TABLE IV.—*Transpiration and Green Weight, in Grams, of Wheat Seedlings Grown in Neutral Solutions and in the same after the Addition of Different Acids.*

Nutrient Solutions. Reaction.	No.	Transpiration, per bottle, 10 plants.	Green weight, per bottle, 10 plants.	Relative transpiration per 20 plants.	Relative green weight per 20 plants.	Alkalinity.*
Neutral........	I	168 198	5.2 5.6	100	100	13.7
	II	165 171	4.9 4.8	100	100	12.5
	III	174 218	4.9 5.5	100	100	15.0
Acid, $\frac{N}{10000}$, by sulfuric acid..	I	155 178	4.6 5.3	91	92	13.0
	II	175 168	5.0 4.5	102	98	13.0
	III	176 194	5.2 5.7	94	105	14.0
Acid, $\frac{N}{5000}$, by sulfuric acid..	I	175 201	4.8 5.9	103	99	13.0
	II	161 175	4.6 4.9	100	98	12.5
	III	186 190	5.2 5.1	96	99	13.5
Acid, $\frac{N}{5000}$, by hydrochloric acid.	I	161 167	5.0 4.9	90	92	13.5
	II	182 178	5.1 5.2	107	106	13.3
	III	177 201	5.1 5.6	96	103	13.0

* Average number of cc. of $\frac{N}{100}$ sulfuric acid required after the last four days' growth of the plants, to make neutral to methyl orange 50 cc. of the nutrient solution which had been made up to the original volume. Ten cc. is equivalent to $\frac{N}{500}$.

Table IV.—Transpiration and Green Weight, in Grams, of Wheat Seedlings, Grown in Neutral Solutions and in the same after the Addition of Different Acids.—Concluded

NUTRIENT SOLUTIONS. Reaction.	No.	Transpiration. per bottle, 10 plants.	Green weight, per bottle, 10 plants.	Relative transpiration per 10 plants.	Relative green weight per 10 plants.	Alkalinity.*
Acid, $\frac{N}{5000}$, by acetic acid...	I	160 191	4.8 5.4	96	95	13.1
	II	190 175	4.9 4.8	109	100	13.0
	III	194 178	5.4 5.2	95	102	15.0

By comparing the figures from the individual bottles, given in the preceding table, it is obvious that in the case of a given solution, the effect of the added acid has not been sufficient to make a change, in the transpiration and green weight, in excess of the probable limit of error. The only instance in which the figures from both bottles were lessened is where the $\frac{N}{5000}$ hydrochloric acid was added to solution I, in which case there was an apparent depression of 11 per cent. in transpiration and 8 per cent. in green weight.

This experiment indicates that an acidity of any less concentration than $\frac{N}{5000}$ would scarcely be expected to influence the amount of growth.

In the following experiments a single nutrient solution, number III, was used, and strict comparisons of certain cereals were undertaken.

* Average number of cc. of $\frac{N}{100}$ sulfuric acid required, after the last four days' growth of the plants, to make neutral to methyl orange 50 cc. of the nutrient solution which had been made up to the original volume. Ten cc. is equivalent to $\frac{N}{500}$.

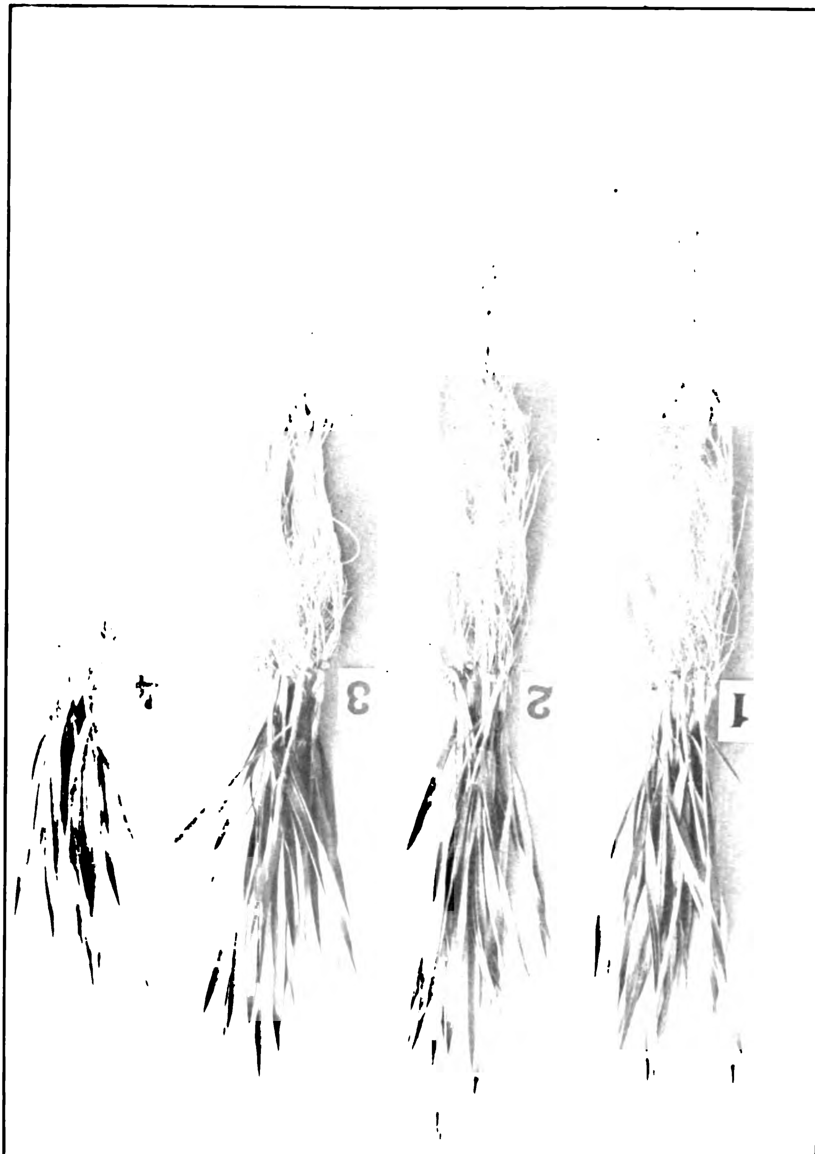
TABLE V.—*Transpiration and Green Weight, in Grams, of Wheat and Barley Seedlings Grown in a Neutral Solution and in the same after the Addition of Acid.*

		Neutral.	Acidity by sulfuric acid, $\frac{N}{5000}$.	Acidity by sulfuric acid, $\frac{N}{2500}$.	Acidity by sulfuric acid, $\frac{N}{1250}$.	Acidity by hydrochloric acid, $\frac{N}{5000}$.	Acidity by hydrochloric acid, $\frac{N}{2500}$.	Acidity by hydrochloric acid, $\frac{N}{1250}$.
Transpiration per bottle, 10 plants.	Wheat.	170.	174.	152.	70.	169.	156.	51.
		184.	177.	156.	62.	160.	152.	69.
	Barley.	150.	128.	99.	54.	127.	112.	59.
		143.	140.	115.	51.	123.	111.	53.
Green weight, per bottle, 10 plants	Wheat.	6.7	6.3	5.1	2.5	5.7	5.5	2.4
	Barley.	6.3	5.8	4.7	2.4	5.5	4.9	2.4
Relative transpiration, per 20 plants.	Wheat.	100.	99.	87.	37.	93.	87.	34.
	Barley.	100.	91.	73.	36.	85.	76.	38.
Relative green weight per 20 plants.	Wheat.	100.	94.	76.	37.	85.	82.	36.
	Barley.	100.	92.	75.	38.	87.	78.	38.
Alkalinity.*	Wheat.	10.	8.2	8.4	1.8	9.	8.2	1.6
	Barley.	8.	7.8	7.5	0.5	9.	9.0	0.2

The results in the preceding table were from seedlings grown between February 27 and March 15, 1907, and afford a comparison of the effect of the sulfuric and hydrochloric acids on the two kinds of seedlings grown under the same conditions.

When acid was added in such an amount that a neutral solution would be changed to one having an acidity of $\frac{N}{5000}$, there was a greater depression caused by hydrochloric acid than by sulfuric acid, and although the relative depression in transpiration caused by the acids

* Average number of cc. of $\frac{N}{100}$ sulfuric acid required after the last four days' growth of the plants, to make neutral to methyl orange 50 cc. of the nutrient solution which had been made up to the original volume. Ten cc. is equivalent to $\frac{N}{500}$.



Neutral.	Acidity, $\frac{N}{5000}$	Acidity, $\frac{N}{2500}$	Acidity, $\frac{N}{1250}$

FIG. 1.—Wheat seedlings grown in a neutral, nutrient solution, and in the same after the addition of sulfuric acid.

Neutral.	Acidity, $\frac{N}{5000}$	Acidity, $\frac{N}{2500}$	Acidity, $\frac{N}{1250}$

FIG. 2.—Barley seedlings grown in a neutral, nutrient solution, and in the same after the addition of sulfuric acid.

was somewhat greater with the barley than with the wheat, there was no appreciable difference in the green weight.

With the $\frac{N}{2500}$ acids, the depression in growth was about the same by both acids, and here again, while there was as before a greater relative depression of transpiration with the barley than with the wheat, there was not an equal difference in green weight.

The $\frac{N}{1250}$ acids produced a uniform depression of a little over sixty per cent. in both transpiration and green weight. Figures 1 and 2 illustrate the effect of the acid upon the roots as well as upon the tops.

The titrations given in the last two lines of the table show how readily the acid solutions were changed to alkaline ones, for four days' growth was sufficient to produce a degree of alkalinity in the solutions to which the acids of the least two concentrations were added, which was practically equal to that produced in the nutrient solution, to which no acid at all had been added. It was shown by allowing solutions to stand in bottles unoccupied by plants, that these changes were not attributable to the bottles.

In the preceding experiments the young seedlings were placed immediately in the solutions in which they were to grow during the experiments, whereas in the test which follows, the seeds were germinated in sand and were placed for two days in a uniform nutrient solution, containing solids equal to about 225 parts per million, before they were entered upon the experiment itself, which continued from May 14 to 27, 1907. The four different kinds of seedlings were grown at the same time and under the same conditions, with the intention of making a strict comparison of the relative effect of the acids upon them.

TABLE VI.—*Transpiration and Green Weight, in Grams, of Wheat, Rye, Barley and Oat Seedlings Grown in a Neutral Solution and in the same after the Addition of Acid.*

		Neutral.	Acidity by sulfuric acid, $\frac{N}{2500}$	Acidity by sulfuric acid, $\frac{N}{1667}$.	Acidity by acetic acid, $\frac{N}{2500}$.	Acidity by acetic acid, $\frac{N}{1667}$.
Transpiration, per bottle, 10 plants.	Wheat.	233.	166.	59.	195.	195.
		248.	112.	73.	171.	143.
	Rye....	179.	147.	76.	116.	143.
		223.	87.	81.	145.	108.
	Barley.	209.	165.	98.	176.	145.
		185.	140.	96.	169.	161.
	Oats...	210.	151.	84.	148.	111.
		144.	134.	78.	176.	80.
Green weight, per bottle, 10 plants.	Wheat.	6.1	5.9	2.6	5.3	5.3
		6.3	4.7	3.9	5.0	4.7
	Rye....	4.5	4.7	3.1	3.5	3.8
		5.6	3.2	2.7	4.8	3.5
	Barley.	6.4	5.6	4.5	5.8	4.6
		5.7	5.2	4.2	5.2	4.9
	Oats...	6.3	4.6	3.4	4.8	3.6
		4.9	4.8	3.5	5.8	3.5
Relative transpiration, per 20 plants.	Wheat.	100.	58.	27.	76.	70.
	Rye....	100.	51.	39.	65.	63.
	Barley.	100.	52.	49.	87.	78.
	Oats...	100.	80.	46.	92.	54.
Relative green weight, per 20 plants.	Wheat.	100.	85.	52.	83.	81.
	Rye....	100.	78.	57.	82.	72.
	Barley.	100.	89.	72.	91.	79.
	Oats...	100.	83.	62.	95.	63.
Alkalinity.*	Wheat.	8.8	5.9	1.8	10.2	9.3
	Rye....	8.3	4.0	2.3	7.3	5.5
	Barley.	8.8	7.9	4.2	10.3	10.3
	Oats...	10.8	6.6	1.1	10.3	8.3

* Average number of cc. of $\frac{N}{100}$ sulfuric acid required after the last three days' growth of the plants to make neutral to methyl orange 50 cc. of the nutrient solution which had been made up to the original volume. Ten cc. is equivalent to $\frac{N}{500}$.

The table shows that the depression caused by each acid is in every case relatively greater when measured by transpiration than by green weight, although this difference is much greater with the sulfuric than with the acetic acid. With $\frac{N}{3500}$ acids, the relative transpiration with the sulfuric acid was twenty less than with the acetic acid, taking the average of the four crops; whereas the difference in green weight similarly considered was only three less. Again, with the $\frac{N}{1667}$ acids, the average relative transpiration was twenty-six less with the sulfuric than with the acetic acid, while with the green weight the difference was thirteen. Although in the case of both concentrations the relative transpirations were considerably less with the sulfuric than with the acetic acid, the difference according to the relative green weights was, as a rule, much less marked.

The titration figures at the bottom of the table show that the solutions were less alkaline after three days' growth in the presence of even the more dilute sulfuric acid, than those to which no acid had been added. As methyl orange is not sensitive to acetic acid, the high apparent alkalinity in the solutions to which this acid was added, will cause no surprise. It is hardly necessary to add that had phenolphthalein been used as an indicator in this instance, instead of methyl orange, the alkalinity would have appeared much less.

Considering now the main object of the experiment, that is, the relative effect of the acids upon the four cereals, and using the green weights as the principal criterion, it may be seen that with $\frac{N}{3500}$ sulfuric acid, the relative depression ranged from 11 per cent. with the barley, to 22 per cent. with the rye. It may be seen at once, however, by looking at the wide variation in the green weights from the individual bottles, in many of the series in this particular experiment, that these differences based upon the average results may be without any particular significance. Take a severe case of disagreement between two parallel bottles, for example, that of the green weights of oats in neutral solution, and it may be seen that in one bottle 4.9 grams were produced and in the other, 6.3 grams. Had

either one of these weights, instead of the average, been taken as 100 in calculating the relative depression caused by the acids, very different results would have been obtained. The same objection must be raised against giving much significance to small relative differences in the action of the acids in general, upon the different seedlings.

The transpiration figures show relatively greater differences due to particular treatments, than the green weights, but they do not enable one to say with any degree of confidence that one cereal is more resistant to these acids than another. It would appear from the relative transpiration figures that oats were more resistant to $\frac{N}{1000}$ sulfuric acid than the other cereals, and yet with the stronger acid the figures do not show it to be any more resistant than barley. In table V the transpiration figures indicated that wheat was more resistant than barley; but, on the whole, the same could not be said after an inspection of the relative transpirations given in table VI.

TABLE VII.—*Transpiration and Green Weight, in Grams, of Barley and Rye Seedlings Grown in a Neutral Solution, and in the same after the Addition of Sulfuric Acid.*

			Neutral.	Acidity by sulfuric acid, $\frac{N}{2500}$.	Acidity by sulfuric acid, $\frac{N}{1667}$.
Transpiration, per bottle, 10 plants.	Barley.		163.	98.	103.
			136.	145.	130.
			145.	113.	106.
	Rye...		154.	137.	117.
			155.	127.	101.
			152.	135.	121.
Green weight, per bottle, 10 plants.	Barley.		6.7	3.9	4.3
			5.8	6.2	5.1
			6.2	5.1	4.4
	Rye....		6.1	4.6	4.6
			6.2	4.4	3.9
			5.5	5.4	4.8
Relative transpiration, 30 plants...	Barley....		100.	80.	76.
	Rye......		100.	86.	73.
Relative green weight, 30 plants.	Barley.....		100.	82.	73.
	Rye......		100.	81.	74.
Alkalinity.*	Methyl orange.	Barley.....	8.0	5.6	4.3
		Rye.......	8.1	6.2	3.2
	Phenolphthalein.	Barley....	8.4	6.5	5.4
		Rye......	8.6	6.7	4.1

* Average number of cc. of $\frac{N}{100}$ sulfuric acid required after the last four days' growth of the plants, to neutralize 50 cc. of the nutrient solution which had been made up to the original volume. Ten cc. is equivalent to $\frac{N}{500}$. With the phenolphthalein, an excess of the sulfuric acid was added, the solution boiled to remove carbon dioxid, and the excess of acid titrated against potassium hydroxid.

TABLE VIII.—*Transpiration and Green Weight, in Grams, of Barley and Rye Seedlings Grown in a Neutral Solution, and in the same after the Addition of Sulfuric Acid.*

		Neutral.	Acidity by sulfuric acid, $\frac{N}{2500}$.	Acidity by sulfuric acid, $\frac{N}{1667}$.
Transpiration, per bottle, 10 plants	Barley..	117.	86.	69.
		99.	98.	83.
		105.	96.	111.
	Rye....	127.	110.	85.
		136.	95.	81.
		112.	109.	81.
Green weight, per bottle, 10 plants.	Barley.	5.4	3.9	3.9
		5.3	4.5	4.1
		4.9	4.3	4.6
	Rye....	5.1	4.1	3.6
		5.1	3.6	3.6
		4.8	4.2	3.7
Relative transpiration, 30 plants.	Barley ...	100.	87.	82.
	Rye......	100.	84.	65.
Relative green weight, 30 plants.	Barley ...	100.	85.	81.
	Rye......	100.	79.	73.
Alkalinity.* Methyl orange	Barley....	9.4	7.2	5.1
	Rye......	9.5	6.8	3.2
Alkalinity.* Phenolphthalein.	Barley....	9.0	5.9	3.9
	Rye......	8.8	6.0	1.7

Table VII records the results of an experiment performed between August 31 and September 14, 1907 and table VIII, one carried on between September 16 and October 1. On account of the indications

* Average number of cc. of $\frac{N}{100}$ sulfuric acid required, after the last four days' growth of the plants, to neutralize 50 cc. of the nutrient solution which had been made up to the original volume. Ten cc. is equivalent to $\frac{N}{500}$. With the phenolphthalein, an excess of the sulfuric acid was added, the solution boiled to remove carbon dioxid, and the excess of acid titrated against potassium hydroxid.

furnished by the experiments which preceded these two, to the effect that no great differences, if any, existed in the resistance of the different seedlings to acid nutrient solutions, it was decided to confine the work to barley and rye, as these two, of the four cereals which have been considered, were the ones which differed most widely as affected by liming.

Conditions which are somewhat unfavorable to the growth of plants naturally give rise to increased individuality, and in this work with acid solutions there were frequently quite wide differences in the growth in two bottles receiving the same treatment. For this reason three bottles, containing ten plants each, were included in each group in the two foregoing experiments, and the results obtained in the case of each individual bottle are given as usual.

The relative transpirations and green weights agree with each other fairly well for a given plant, and from table VII it will be seen that by either criterion, the two cereals were about equally affected by the acid, the widest difference being in the relative transpirations with the $\frac{N}{1500}$ acid solution, namely: between barley at 80, and rye at 86. Because of the rather wide differences in the transpiration of the plants from the individual bottles containing the barley, however, this small difference cannot be considered as having much significance. According to table VIII, the depression caused by both degrees of acidity was greater with the rye than with the barley, both by transpiration and green weight.

Owing to the tendency of the seedlings to counteract the acidity of the solutions to which acid had been added, the effect of a given concentration of acid would be expected to vary considerably with a particular plant, depending upon the frequency with which the solutions were changed. Differences in climatic conditions also would be expected to exert considerable effect, either directly or indirectly, upon the degree of injury which the seedlings would receive. It should not be expected, therefore, that the depression in growth would necessarily be greater with each comparatively small increase in the concentration of the added acid, unless other conditions were

constant. For this reason the results of one experiment cannot be compared strictly with those of another. Nevertheless, in order to give the reader a general idea of the effect which acids exert in a nutrient solution, the following table has been compiled from those which precede.

Table IX.—*Relative Green Weights of Cereal Seedlings Grown in Nutrient Solutions of Different Degrees of Acidity.* (*Weight in "Neutral" Solution as* 100)

	$\frac{N}{5000}$	$\frac{N}{2500}$	$\frac{N}{1667}$	$\frac{N}{1250}$
Wheat—				
Table II, HCl	..	..	51	..
Table IV, HCl	100	..	..	..
Table IV, H_2SO_4	99	..	..	..
Table V, HCl	85	82	..	36
Table V, H_2SO_4	94	76	..	37
Table VI, H_2SO_4	..	85	52	..
Barley—				
Table III, HCl	..	..	..	..
Table V. HCl	87	78	..	38
Table V, H_2SO_4	92	75	..	38
Table VI H_2SO_4	..	89	72	..
Table VII, H_2SO_4	..	82	73	..
Table VIII, H_2SO_4	..	85	81	..
Rye—				
Table VI, H_2SO_4	..	78	57	..
Table VII, H_2SO_4	..	81	74	..
Table VIII, H_2SO_4	..	79	73	..
Oats—				
Table VI, H_2SO_4	..	83	62	..
Average	93	81	64	37

The preceding table is not presented for the purpose of pointing out differences in the action of the two acids, nor their individual effect upon the different kinds of seedlings; but principally to show, in a very general way, the effect of acid in nutrient solutions on seedlings grown under somewhat varying conditions.

The authors are not unmindful of the work of other investigators on the effect of acids on seedlings, but owing to the different manner

of measuring the effects, it would be futile to attempt any strict comparisons. Cameron and Breazeale* have shown that the strong mineral acids when used alone were toxic to wheat seedlings when the strength was only about $\frac{N}{15000}$; but in the presence of a certain amount of potassium, and again of calcium, the limit was changed respectively, to about $\frac{N}{7000}$ and $\frac{N}{3500}$. They accepted the death of the tips of the roots for a short distance from the ends, as a measure of the toxic limit, or "concentrations just permitting growth to continue in upwards of 60 per cent. of the seedlings were considered toxic." These figures show the great influence of the accompanying salts upon the toxicity of acid solutions, and it is obvious from the results in table IX, that, with complete nutrient solutions, seedlings are able to live when placed in a relatively strong acid solution. Even in the presence of a nutrient solution with an acidity equal to $\frac{N}{1350}$, which was changed every two to four days, the growth during two to three weeks was one-third of that in the unacidulated solution. The roots were very much shortened as may be seen by consulting figures I and II, and they showed very little tendency to branch; but the tops remained of normal color, and the plants exhibited no sure signs of death within the two to three weeks. Owing to the disturbance caused by removing the seeds, these experiments were conducted without their removal. The plants were suspended in such a way that the seeds were above the solution. The contents of the seeds had usually been practically all absorbed by about the sixth day.

In the first part of this paper the effect of liming upon the growth to maturity of certain of our common cereals in the field was shown, and particularly the great difference between rye and barley in this respect. Rye was only slightly if at all benefited, whereas an increase of from 100 to 200 per cent., due to the liming, was not uncommon with the barley. Furthermore, a difference in the two cereals with respect to liming was plainly shown in the first few weeks of their growth in the field, or within a period of growth in

* Journal of Physical Chem. 8, 11-12 (1904).

which the experiments in solution herein described were conducted. One might be led to believe from this, that the barley seedlings would be much more susceptible than the rye seedlings to injury from acidity in nutrient solutions, but such appears not to be the case, as may be seen by a comparison of the average depression in the green weights of these two cereals when grown under identical conditions. In table VI with two different strengths of sulfuric acid, as well as with the acetic acid, the average depression was in each case greater with the rye than with the barley. In table VII, there was practically no difference in the two cereals. In table VIII, the rye again suffered the greater depression, especially with the greater degree of acidity. Although one would hesitate to conclude from a careful inspection of the data presented herewith, that rye seedlings were more susceptible than barley seedlings to injury from acid nutrient solutions, there is certainly no evidence whatever afforded by these experiments, that the reverse is true.

It should not be concluded from these solution experiments that the very beneficial effect of liming, in the case of field experiments with barley, might not be due directly to the neutralization of acid substances in the soil, for of course the conditions of growth in the field and in solution are very different, and there are many kinds of acid substances. Nevertheless these results indicate that other chemical changes as well as those of neutralization, must be studied before the remarkable differences exhibited by plants as to the effect of liming upon them will be understood.

It would be unwise to discontinue the use of tests for soil acidity as an indication of the lime requirements of a soil so long as they are useful in farm practice, even if the beneficial action of calcium carbonate and other alkaline material upon extracts of certain infertile soils is due to some other effect than that of direct neutralization of the acidity, which appears to Livingston *et al** to be the case; and even if wide application were made of the suggestion of Cameron and Bell† that the reddening of blue litmus paper which frequently

* Bureau of Soils, U. S. Dept. of Agr., Bul. 36, 41.
† Bureau of Soils, Bul. 30. 59-60.

occurs when this material is placed in intimate contact with moist soil, may be due to absorption effects. So far as is now known, a soil which may possess such strong absorptive properties for bases as to be able to remove the base from the coloring matter of blue litmus paper thereby leaving a pink color, as suggested by Cameron and Bell, may need to have this demand satisfied by the addition of basic material; and if an acid reaction should prove to be a usual accompaniment of certain toxic substances, as it appears to Livingston *et al*,* then the litmus paper and other tests for soil acidity may continue to serve a useful purpose.†

SUMMARY.

The published results of the field experiments at this Station, concerning the effect of liming on the growth of a large variety of plants show that, among the common cereals, rye and barley might be selected as two crops which are very differently affected. Under conditions showing very little influence of the liming upon the growth of rye, the growth of the barley plants was quite commonly increased 100 to 200 per cent.

The principal object of the experiments described in this paper was to secure some indications as to whether varieties of plants which were most benefited by liming, were likewise most susceptible to injury by certain acids, when their seedlings were grown in nutrient solutions possessing definite degrees of acidity.

After some preliminary experiments with different plants and solutions, attention was given especially to the relative effect upon rye and barley, the two crops mentioned above, of the addition of acids to the nutrient solution in which they were grown.

The water-culture experiments showed that barley seedlings were *not* more susceptible than rye seedlings to injury from acidified

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* Bureau of Soils, 36, 42.

† Attention has been called repeatedly at this Station to the possibility of acid or non-acid toxic compounds accompanying the soil acidity or the lack of basic substances. (Ann. Repts. 8, 260 (1895); 9, 307 (1896); 13, 293 (1900).

nutrient solutions, even though the field results proved that barley received very much more benefit than rye, from liming.

While recognizing the caution which should be exercised in drawing conclusions concerning growth in the soil, from results secured by solution cultures, it seems certain, in searching for an explanation of the great differences exhibited by different kinds of plants in respect to liming, that other chemical properties of lime should be prominently studied along with its function as a corrector of acidity, even when attention has been given to the plant-food ingredients.

According to the method of experimentation employed, the growth of wheat, rye, barley, and oat seedlings was not materially influenced by any degree of alkalinity which is insufficient to cause precipitation from an ordinary nutrient solution.

The growth of these same seedlings, in nutrient solutions, was likewise scarcely affected by an acidity equal to about $\frac{N}{5000}$ or less. A depression in green weight of about 20 per cent. resulted when the acidity equalled $\frac{N}{2500}$, and an increase in the acidity to about $\frac{N}{1700}$ and $\frac{N}{1250}$, decreased the production of green weight around 40 and 60 per cent., respectively.

The very marked property of the seedlings of rendering the nutrient solutions alkaline was measured by titrations against standard acid at the end of the final periods of growth.

Even if it should be proven beyond question that the so-called acid soils are not injurious to the growth of certain plants because of a noxious degree of acidity, but rather owing to accompanying toxic compounds, it would surely be unwise to discontinue the use of the litmus paper or other tests for soil acidity so long as valuable indications are afforded by them concerning the need of applications of basic material.

REPORT OF METEOROLOGIST.

NATHANIEL HELME.

SUMMARY, JULY 1, 1906, TO JUNE 30, 1907.

Temperature, Fahrenheit.

Maximum	90°	September 19, 1906.
Minimum	—9°	January 24, February 23, 1907.
Highest daily mean	76.5°	August 23, September 19, 1906.
Lowest daily mean	0.5°	January 24, 1907.
Highest monthly mean	70.4°	August, 1906.
Lowest monthly mean	20.3°	February, 1907.
Mean of the year	46.5°	

Precipitation. (Rain and melted Snow.)

Total for the year...............48.01 inches.
Largest monthly................ 5.82 inches, December, 1906.
Least monthly.................. 1.02 inches, August 1906.
Greatest in any 24 consecutive
hours........................ 2.31 inches, October 20, 1906.
Snowfall (unmelted).............63 inches; December, 7 inches; January, 12 inches; February, 30 inches; March, 12 inches; April, 2 inches.

Prevailing Winds.

Northeast; October, 1906. Southwest; July, 1906. West; August, September, November, December, 1906; January, February, March, April, May, June, 1907.

Weather.

Number of clear days in the year	136
Partly cloudy days	114
Cloudy days	115
Days with .01 inch or more of precipitation	120

The principal characteristics of the weather for each month were as follows:

Cloudy and wet weather prevailed in July to such an extent that the harvesting of the hay crop was seriously interfered with, and at the end of the month a large quantity of grass remained uncut. The mean temperature was slightly below the average for the month.

The total precipitation for August was the least for the month in the entire Station record, covering nineteen years, it being about one-fourth of the average for the month during that time. The mean temperature was about 2° above the normal for the month.

The mean temperature of September was above the normal for the month, and the highest temperature of the summer was registered on the 19th. The total rainfall was slightly above the average.

The total precipitation for October was three times as much as that for the same month in 1905, and the largest for the month since 1898. The mean temperature was but slightly above the normal for the month.

The mean temperature and total precipitation for November were each below the normal for the month. There were flurries of snow in the afternoon of the 13th, and a trace of snow fell on the 28th.

Cloudy weather prevailed during the month of December, and precipitation in the form of rain or snow was very frequent. There were but four clear days in the month. The mean temperature was below the normal.

The mean temperature of January was very near, and the precipitation slightly below, the normal of the month. A large quantity of ice was harvested during the latter part of the month.

With the exception of January, 1893, February was the coldest month on the record for eighteen years. There was snow on the ground throughout the month.

The maximum temperature of 76° was the highest for March during the record of eighteen years. The mean temperature was slightly above, and the precipitation about 2 inches less than, the normal for the month.

It was the coldest April on the Station record. At the close of the month the season was very backward, and but little planting had been done on account of the low temperature of the ground. The mean temperature was nearly 4° below the normal for the month.

May was another cold month, and the same remark is to be made concerning it as was made of the month previous, namely, that it was the coldest May on the records at the Station. The mean temperature was more than 5° below the average for the month.

The first part of June was cold, and there was frost on low land on the 1st, 12th, and 13th. The high temperatures of the last part of the month helped to bring the record very nearly up to the normal.

The following tables show the maximum, minimum, and mean temperatures, character of day, precipitation, and prevailing wind for each day in the year, a summary by months for 1906–1907, and also a general summary from January 1, 1890, to June 30, 1907, inclusive:

WEATHER SUMMARY FOR JULY, 1906.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	74°	53°	63.5°	....	N.	Fair.
2	77	58	67.5	.23	S. W.	Fair.
3	81	63	72.0	.08	S. E.	Fair.
4	70	64	67.0	.82	S.	Cloudy.
5	73	57	65.0	....	E.	Clear.
6	70	54	62.0	....	E.	Fair.
7	64	50	57.0	.50	N. E.	Rainy.
8	72	57	64.5	.15	S. E.	Cloudy.
9	70	59	64.5	.04	W.	Cloudy.
10	82	59	70.5	.02	S. W.	Clear.
11	78	61	69.5	....	N.	Clear.
12	77	56	66.5	....	W.	Clear.
13	80	58	69.0	....	S. W.	Clear.
14	76	56	66.0	....	N. E.	Fair.
15	81	54	67.5	....	Variable.	Fair.
16	80	58	69.0	.40	Variable.	Clear.
17	82	65	73.5	.11	S. W.	Fair.
18	83	68	75.5	....	W.	Clear.
19	83	63	73.0	....	S. E.	Clear.
20	80	64	72.0	....	S.	Fair.
21	75	66	70.5	.28	S.	Cloudy.
22	86	66	76.0	....	S. W.	Fair.
23	75	68	71.5	.07	S.	Cloudy.
24	72	64	68.0	.95	S.	Rainy.
25	72	58	65.0	....	N. E.	Fair.
26	68	54	61.0	....	N. E.	Foggy.
27	74	59	66.5	....	N. E.	Cloudy.
28	79	60	69.5	....	W.	Cloudy.
29	78	64	71.0	....	S. W.	Cloudy.
30	76	67	71.5	.40	S.	Cloudy.
31	85	66	75.5	....	W.	Fair.
Sum........	2,373	1,869	2,121	4.05	....	....
Mean.......	76.5	60.3	68.4	....	....	....

Clear days, 8; Fair, 11; Cloudy, 12; Prevailing wind, S. W; Maximum temperature, 86°; Minimum temperature, 50°.

WEATHER SUMMARY FOR AUGUST, 1906.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	70°	65°	67.5°	.16	N. E.	Foggy.
2	71	61	67.0	.03	N. E.	Cloudy.
3	72	62	67.0	.03	N. E.	Cloudy.
4	80	62	71.0	Trace.	S. E.	Cloudy.
5	87	65	76.0	....	Variable.	Clear.
6	87	66	76.5	....	S. W.	Clear.
7	89	67	78.0	....	S. W.	Fair.
8	70	65	67.5	.22	N. E.	Cloudy.
9	81	61	71.0	....	N. E.	Clear.
10	70	57	63.5	.23	N. E.	Fog and Rain
11	86	62	74.0	....	S. W.	Fair.
12	87	68	77.5	....	W.	Clear.
13	76	55	65.5	....	Variable.	Clear.
14	81	55	68.0	....	W.	Clear.
15	75	53	64.0	....	N. W.	Clear.
16	79	50	64.5	....	Variable.	Clear.
17	83	58	70.5	....	S.	Clear.
18	84	58	71.0	....	W.	Clear.
19	87	62	74.5	....	W.	Clear.
20	83	66	74.5	....	W.	Fair.
21	75	69	72.0	Trace.	S. W.	Cloudy.
22	82	68	75.0	....	S.	Fair.
23	85	68	76.5	....	S. W.	Fair.
24	73	57	65.0	.29	N. E.	Fair.
25	73	51	62.0	....	S. E.	Clear.
26	81	59	70.0	....	S.	Clear.
27	78	65	71.5	.04	S.	Cloudy.
28	80	64	72.0	.02	W.	Cloudy.
29	78	61	69.5	....	S. W.	Clear.
30	82	62	72.0	....	S. W.	Cloudy.
31	80	58	69.0	....	N. W.	Clear.
Sum........	2,465	1,902	218.4	1.02	....	....
Mean.......	79.5	61.3	70.4	....	....	....

Clear days, 16; Fair, 9; Cloudy, 6; Prevailing wind, West; Maximum temperature, 89°; Minimum temperature, 50°.

WEATHER SUMMARY FOR SEPTEMBER, 1906.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	72°	52°	62.0°	....	N. W.	Clear.
2	76	44	60.0	....	S. W.	Fair.
3	83	62	72.5	.15	W.	Fair.
4	74	49	61.5	....	N. W.	Clear.
5	72	41	56.5	....	Variable.	Clear.
6	78	46	62.0	....	S. W.	Clear.
7	84	58	71.0	....	N. W.	Clear.
8	72	54	63.0	....	N. E.	Clear.
9	79	51	65.0	....	S. W.	Clear.
10	82	61	71.5	....	N.	Clear.
11	73	57	65.0	....	S. E.	Clear.
12	70	57	63.5	.28	S. E.	Fair.
13	77	62	69.5	.22	S.	Cloudy.
14	76	58	67.0	.75	N. W.	Fair.
15	66	50	58.0	....	N. E.	Clear.
16	68	44	56.0	....	N. E.	Clear.
17	72	50	61.0	....	S. E.	Clear.
18	85	56	70.5	....	S. W.	Clear.
19	*90	63	76.5	....	W.	Clear.
20	78	62	70.0	....	E.	Cloudy.
21	82	63	72.5	.35	N.	Clear.
22	66	59	62.5	2.28	E.	Rainy.
23	77	61	69.0	....	W.	Fair.
24	66	46	56.0	....	N. W.	Clear.
25	65	39	52.0	....	S. E.	Clear.
26	70	42	56.0	....	S.	Clear.
27	67	55	61.0	.13	S. W.	Fair.
28	70	49	59.5	....	N. E.	Clear.
29	67	48	57.5	....	S. E.	Fair.
30	69	46	57.5	.12	N.	Cloudy.
Sum........	2,226	1,585	1905.5	4.28	....	....
Mean.......	742	52.8	63.5	....	....	....

Clear days, 19; Fair, 7; Cloudy, 4; Prevailing wind, West; Maximum temperature, 90°; Minimum temperature, 39°.

WEATHER SUMMARY FOR OCTOBER, 1906.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	61°	37°	49.0°	....	S. E.	Fair.
2	66	45	55.5	.03	N. E.	Fair.
3	68	44	56.0	....	E.	Cloudy.
4	71	47	59.0	....	E.	Fair.
5	77	52	64.5	....	N. E.	Clear
6	68	52	60.0	.82	S. E.	Cloudy.
7	60	41	50.5	....	W.	Fair.
8	61	36	48.5	....	S. E.	Clear.
9	70	46	58.0	.18	S.	Rainy.
10	52	42	47.0	1.44	W.	Fair.
11	51	35	43.0	.08	W.	Fair.
12	53	29	41.0	....	W.	Clear.
13	55	30	42.5	....	E.	Clear.
14	60	34	47.0	....	N. E.	Clear.
15	65	40	52.5	....	N. E.	Clear.
16	65	44	54.5	....	N. E.	Fair.
17	53	46	49.5	....	N. E.	Cloudy.
18	62	46	54.0	....	N. E.	Cloudy.
19	68	52	60.0	....	N. E.	Fair.
20	65	56	60.5	2.31	E.	Rainy.
21	57	49	53.0	....	N. E.	Cloudy.
22	54	47	50.5	....	N. E.	Cloudy.
23	69	49	59.0	....	Variable.	Clear.
24	58	44	51.0	....	N. E.	Fair.
25	68	51	59.5	.46	S.	Fair.
26	62	40	51.0	....	N. W.	Clear.
27	66	40	53.0	....	S. E.	Clear.
28	62	43	52.5	....	W.	Clear.
29	47	33	40.0	....	W.	Fair.
30	53	31	42.0	....	S. E.	Cloudy.
31	51	35	43.0	.36	N. E.	Cloudy.
Sum........	1,898	1,316	1,607	5.68	....	....
Mean.......	61.2	42.4	51.8	....	....	....

Clear days, 10; Fair, 11; Cloudy, 10; Prevailing wind, N. E; Maximum temperature, 77°; Minimum temperature, 29°.

WEATHER SUMMARY FOR NOVEMBER, 1906.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	47°	30°	38.5°	....	N. W.	Fair.
2	44	33	38.5	....	N. W.	Cloudy.
3	61	34	47.5	....	N. W.	Clear.
4	54	33	43.5	....	N. W.	Clear.
5	55	25	40.0	....	N.	Clear.
6	55	31	43.0	....	N. W.	Clear.
7	52	29	40.5	....	N. W.	Clear.
8	48	25	36.5	....	N. W.	Clear.
9	50	28	39.0	....	S. E.	Fair.
10	55	40	47.5	Trace.	N. W.	Fair.
11	45	37	41.0	1.34	N. E.	Rainy.
12	44	32	38.0	....	W.	Fair.
13	42	27	34.5	....	W.	Clear.
14	37	22	29.5	....	W.	Clear.
15	41	23	32.0	1.63	N. E.	Rainy.
16	41	30	35.5	....	N. W.	Fair.
17	52	28	40.0	....	W.	Clear.
18	62	44	53.0	....	S. W.	Cloudy.
19	64	49	56.5	.13	W.	Fair.
20	60	46	53.0	....	S. W.	Cloudy.
21	48	37	42.5	.16	E.	Cloudy.
22	57	39	48.0	.10	W.	Fair.
23	47	32	39.5	....	W.	Clear.
24	42	28	35.0	....	W.	Clear.
25	50	25	37.5	....	W.	Clear.
26	49	36	42.5	.03	W.	Cloudy.
27	52	34	43.0	....	W.	Fair.
28	34	30	32.0	.09	N.	Rainy.
29	34	22	28.0	....	N. W.	Clear.
30	41	18	29.5	....	N. W.	Fair.
Sum........	1,463	947	1,205	3.48	....	....
Mean........	48.8	31.6	40.2	....	....	....

Clear days, 13; Fair, 9; Cloudy, 8; Prevailing wind, West; Maximum temperature, 64°; Minimum temperature, 18°.

WEATHER SUMMARY FOR DECEMBER, 1906.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	45°	31°	38.0°	.05	W.	Fair.
2	32	11	21.5	....	W.	Fair.
3	38	17	27.5	.23	W.	Snowy.
4	17	2	9.5	....	W.	Clear.
5.	37	9	23.0	....	W.	Cloudy.
6	52	28	40.0	.85	S.	Rainy.
7	47	5	26.0	.05	W.	Fair.
8	12	—1	5.5	....	W.	Fair.
9	20	10	15.0	.10	N. E.	Cloudy and snow.
10	47	17	32.0	.60	N.	Rainy.
11	39	17	28.0	....	N. W.	Fair.
12	28	9	18.5	....	N. E.	Fair.
13	38	19	28.5	.03	N.	Fair.
14	38	26	32.0	....	N. E.	Fair.
15	50	28	39.0	.10	S.	Cloudy.
16	46	32	39.0	....	W.	Cloudy.
17	33	29	31.0	.23	W.	Cloudy.
18	31	12	21.5	....	N. W.	Clear.
19	32	6	19.0	....	E.	Clear.
20	43	15	29.0	.72	N. E.	Rainy.
21	47	34	40.5	.24	S. W.	Cloudy.
22	41	27	34.0	.29	N. E.	Fair.
23	33	13	23.0	....	W.	Fair.
24	23	7	15.0	....	N. W.	Cloudy.
25	30	15	22.5	....	W.	Cloudy.
26	32	18	25.0	....	W.	Clear.
27	42	19	30.5	.05	W.	Fair.
28	40	31	35.5	....	W.	Fair.
29	47	31	39.0	....	Variable.	Cloudy.
30	41	38	39.5	....	N. E.	Cloudy.
31	51	35	43.0	2.28	N. E.	Rainy.
Sum........	1,152	590	871	5.82	....	....
Mean.......	37.1	19	28.0	....	....	....

Clear days, 4; Fair, 12; Cloudy, 15; Prevailing wind, West; Maximum temperature, 52° Minimum temperature, —1°.

WEATHER SUMMARY FOR JANUARY, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	53°	38°	45.5°	....	W.	Fair.
2	48	30	39.0	....	W.	Clear.
3	40	29	34.5	.12	E.	Rainy.
4	51	35	43.0	.52	S. W.	Rainy.
5	45	28	36.5	....	W.	Clear.
6	45	28	36.5	....	Variable.	Clear.
7	61	34	47.5	.20	S. W.	Clear.
8	47	36	41.5	....	E.	Cloudy.
9	43	18	30.5	.03	W.	Fair.
10	35	10	22.5	....	S. W.	Fair.
11	42	28	35.0	....	W.	Fair.
12	37	28	32.5	.60	E.	Snow and rain
13	37	23	30.0	....	N.	Fair.
14	37	28	32.5	.78	N. E.	Rainy.
15	36	26	31.0	.02	W.	Cloudy.
16	26	7	15.5	....	W.	Fair.
17	9	—2	3.5	.25	N.	Snowy.
18	33	9	21.0	.05	N. E.	Fog and rain.
19	42	29	35.5	.60	E.	Rain and fog.
20	53	36	44.5	....	S. W.	Fair.
21	36	13	24.5	....	W.	Clear.
22	35	10	22.5	.18	S. W.	Snow and rain
23	27	0	13.5	....	W.	Clear.
24	10	—9	0.5	....	N. W.	Fair.
25	21	2	11.5	.25	N. E.	Snowy.
26	25	13	19.0	.33	N. E.	Snow and rain
27	22	10	16.0	....	N.	Cloudy.
28	28	8	18.0	....	W.	Clear.
29	30	9	19.5	....	W.	Fair.
30	32	16	24.0	.18	W.	Fair.
31	28	1	14.5	....	E.	Fair.
Sum........	1,114	571	842.5	4.11	....	....
Mean.......	35.9	18.4	27.2	....	....	....

Clear days, 7; Fair, 11; Cloudy, 13; Prevailing wind, West; Maximum temperature, 61°; Minimum temperature, —9°.

WEATHER SUMMARY FOR FEBRUARY, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	33°	24°	28.5°	1.21	N. E.	Snow and rain
2	40	31	38.5	....	W.	Cloudy.
3	38	17	27.5	....	W.	Fair.
4	22	12	17.0	.40	N. E.	Snowy.
5	22	10	16.0	.60	N.	Snowy.
6	20	4	12.0	....	N. W.	Clear.
7	28	—6	11.0	....	S. W.	Clear.
8	31	13	20.0	....	S. W.	Fair.
9	30	10	20.0	....	N. W.	Clear.
10	34	15	24.5	.10	Variable.	Fair.
11	34	9	21.5	....	W.	Clear.
12	12	—4	4.0	....	W.	Clear.
13	26	—6	10.0	....	S. W.	Clear.
14	45	25	35.0	....	S. W.	Clear.
15	38	20	29.0	....	N. W.	Clear.
16	37	17	27.0	....	W.	Cloudy.
17	40	19	29.5	....	W.	Fair.
18	29	11	20.0	....	Variable.	Clear.
19	38	12	25.0	.27	Variable.	Snow and rain
20	40	25	32.5	.50	N. E.	Snowy.
21	38	13	25.5	....	W.	Clear.
22	19	2	10.5	....	W.	Clear.
23	12	—9	1.5	....	W.	Clear.
24	26	—6	10.0	.67	E.	Snow and rain
25	35	16	25.5	....	W.	Clear.
26	25	4	14.5	....	W.	Clear.
27	28	8	18.0	....	N. E.	Fair.
28	30	—1	14.5	....	E.	Fair.
Sum........	850	285	567.5	3.75	....	....
Mean.......	30.4	10.2	20.3	....	....	....

Clear days, 14; Fair, 7; Cloudy, 7; Prevailing wind West; Maximum temperature, 45°; Minimum temperature, —9°.

WEATHER SUMMARY FOR MARCH, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	33°	15°	24.0°	....	N. E.	Fair.
2	39	27	33.0	.59	W.	Rainy.
3	42	29	35.5	....	W.	Cloudy.
4	32	20	26.0	.13	N. W.	Cloudy.
5	34	13	23.5	....	S. W.	Clear.
6	32	17	24.5	....	N. W.	Clear.
7	35	12	23.5	....	Variable.	Clear.
8	32	14	23.0	.18	E.	Fair.
9	39	17	28.0	....	W.	Clear.
10	30	17	23.5	.80	N. E.	Snowy.
11	38	22	30.0	....	N. W.	Clear.
12	42	20	31.0	....	S.	Fair.
13	40	33	36.5	.30	S.	Rainy.
14	47	33	40.0	.03	S. W.	Rain and fog.
15	43	30	36.5	....	W.	Clear.
16	44	28	36.0	....	W.	Clear.
17	52	29	40.5	Trace.	S. W.	Fair.
18	45	28	36.5	.15	N. E.	Fair.
19	38	24	31.0	.49	S. E.	Rainy.
20	42	30	36.0	....	N. W.	Clear.
21	50	23	36.5	....	W.	Clear.
22	56	32	44.0	....	W.	Cloudy.
23	72	41	56.5	....	W.	Cloudy.
24	48	31	39.5	.52	E.	Rain and snow.
25	42	22	32.0	....	N.	Clear.
26	47	25	36.0	....	S. W.	Fair.
27	52	35	43.5	....	E.	Fair.
28	72	36	54.0	....	S. W.	Cloudy.
29	75	45	60.0	....	Variable.	Fair.
30	76	40	58.0	....	W.	Clear.
31	50	37	43.5	....	E.	Cloudy.
Sum........	1,419	825	1,122	3.19	....	....
Mean.......	45.8	26.6	36.2	....	....	....

Clear days, 11; Fair, 9; Cloudy, 11; Prevailing wind, West; Maximum temperature, 76°; Minimum temperature, 12°.

WEATHER SUMMARY FOR APRIL, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	37°	29°	33.0°	.56	N.	Rain and snow.
2	42	25	33.5	....	N. W.	Fair.
3	47	23	35.0	....	S.	Clear.
4	57	27	42.0	....	S.	Clear.
5	60	38	49.0	.05	S.	Cloudy.
6	47	25	36.0	....	N.	Clear.
7	42	26	34.0	....	N. E.	Fair.
8	40	30	35.0	.88	N. E.	Rain, snow, and hail.
9	36	27	31.5	.93	N. E.	Snow and rain
10	41	30	35.5	.18	W.	Cloudy.
11	46	28	37.0	....	N. W.	Fair.
12	55	28	41.5	....	Variable.	Fair.
13	37	32	34.5	.35	N. W.	Snow and rain
14	53	33	43.0	....	N. W.	Fair.
15	52	30	41.0	....	W.	Clear.
16	52	28	40.0	....	S. W.	Fair.
17	51	31	41.0	.07	W.	Clear.
18	52	30	41.0	....	W.	Clear.
19	36	28	32.0	.17	W.	Rain and snow.
20	49	25	37.0	....	W.	Clear.
21	50	23	36.5	....	W.	Clear.
22	58	28	43.0	....	W.	Clear.
23	55	40	47.5	....	E.	Cloudy.
24	56	40	48.0	.40	N. W.	Fair.
25	58	40	49.0	....	S. W.	Clear.
26	63	45	54.0	.15	S. W.	Cloudy.
27	55	39	47.0	.08	N. E.	Cloudy.
28	52	35	43.5	.22	N. E.	Showery.
29	68	41	54.5	....	S. E.	Cloudy.
30	66	47	56.5	....	S.	Foggy.
Sum........	1,513	951	1,232	4.04	....	....
Mean.......	50.4	31.7	41	....	....	....

Clear days, 10; Fair, 8; Cloudy, 12; Prevailing wind, West; Maximum temperature, 68°; Minimum temperature, 23°.

WEATHER SUMMARY FOR MAY, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	67°	49°	58.0°	.06	W.	Cloudy.
2	54	38	46.0	....	N. E.	Fair.
3	50	32	41.0	....	N. E.	Fair.
4	57	35	46.0	.95	Variable.	Rainy.
5	58	30	44.0	....	W.	Clear.
6	47	35	41.0	1.29	E.	Rainy.
7	58	46	52.0	....	N. E.	Cloudy.
8	60	45	52.5	....	E.	Cloudy.
9	50	43	46.5	.33	N. E.	Rainy.
10	66	38	52.0	.05	S. W.	Cloudy.
11	49	35	42.0	.29	N. W.	Fair.
12	52	29	40.5	....	S. W.	Clear.
13	58	38	48.0	....	S. W.	Clear.
14	85	45	65.0	....	W.	Clear.
15	50	43	46.5	....	E.	Cloudy and foggy.
16	63	48	55.5	.02	S. W.	Cloudy.
17	62	50	56.0	.42	N. E.	Cloudy.
18	72	46	59.0	....	S. W.	Fair.
19	77	50	63.5	....	S. W.	Fair.
20	63	44	53.5	.38	W.	Fair.
21	55	34	44.5	....	W.	Clear.
22	61	35	48.0	....	W.	Clear.
23	58	40	49.0	....	Variable.	Cloudy.
24	65	38	51.5	....	Variable.	Clear.
25	58	39	48.5	....	N. E.	Clear.
26	48	39	43.5	.50	E.	Rainy.
27	54	45	49.5	1.32	N. E.	Rainy.
28	53	39	46.0	....	N. W.	Clear.
29	62	37	49.5	....	N. W.	Clear.
30	62	42	52.0	....	N. E.	Fair.
31	62	45	53.5	.03	E.	Fair.
Sum........	1,836	1,250	1,543	5.64	....	....
Mean.......	59.2	40.3	49.8	....	....	....

Clear days, 10; Fair, 9; Cloudy, 12; Prevailing wind, West; Maximum temperature, 85°; Minimum temperature, 29°.

WEATHER SUMMARY FOR JUNE, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	61°	39°	50.0°	....	S. E.	Clear.
2	48	42	45.0	1.28	N. E.	Rainy.
3	50	45	47.5	....	N. E.	Fair.
4	68	40	54.0	....	S. W.	Clear.
5	53	46	49.5	.64	E.	Rainy.
6	65	46	55.5	.03	W.	Fair.
7	68	45	56.5	....	S. W.	Clear.
8	71	48	59.5	....	S. W.	Clear.
9	67	48	57.5	.09	Variable.	Clear.
10	54	43	48.5	....	N.	Fair.
11	65	39	52.0	....	S. W.	Fair.
12	69	41	55.0	....	S. W.	Clear.
13	69	44	56.5	....	S. W.	Clear.
14	62	48	55.0	....	S. E.	Cloudy.
15	75	48	61.5	.05	Variable.	Fair.
16	82	51	66.5	....	W.	Clear.
17	83	56	59.5	....	W.	Clear.
18	80	59	69.5	....	W.	Clear.
19	74	57	65.5	....	S. W.	Fair.
20	71	55	63.0	....	S. W.	Fair.
21	82	57	69.5	....	S.	Fair.
22	86	60	73.0	....	Variable.	Clear.
23	80	58	69.0	....	S. W.	Clear.
24	80	55	67.5	....	W.	Fair.
25	85	60	72.5	....	S. W.	Fair.
26	85	60	72.5	Trace.	W.	Fair.
27	73	55	64.0	....	W.	Clear.
28	82	51	66.5	....	W.	Clear.
29	73	59	66.0	.06	E.	Cloudy.
30	70	57	63.5	.80	S.	Cloudy.
Sum........	2,131	1,512	1,821.5	2.95	....	....
Mean.......	71	50.4	60.7	....	....	....

Clear days, 14; Fair, 11; Cloudy, 5; Prevailing wind, West; maximum temperature, 85°; Minimum temperature, 39°.

SUMMARY BY MONTHS, 1906–1907.

MONTHS.	Maximum Temperature.	Minimum Temperature.	Mean Temperature.	Precipitation (rain and melted snow), inches.	Snowfall (unmelted).	Clear Days.	Partly Cloudy Days.	Cloudy Days.	Days with .01 inch or more of Precipitation.	Prevailing Winds.
1906.										
July	86°	50°	68.4°	4.05	......	8	11	12	13	S. W.
August	89°	50°	70.4°	1.02	......	16	9	6	8	W.
September	90°	39°	63.5°	4.28	......	19	7	4	8	W.
October	77°	29°	51.8°	5.68	......	10	11	10	8	N. E.
November	64°	18°	40.2°	3.48	......	13	9	8	7	W.
December	52°	—1°	28.0°	5.82	7	4	12	15	14	W.
1907.										
January	61°	—9°	27.2°	4.11	12	7	11	13	14	W.
February	45°	—9°	20.3°	3.75	30	14	7	7	7	W.
March	76°	12°	36.2°	3.19	12	11	9	11	9	W.
April	68°	23°	41.0°	4.04	2	10	8	12	12	W.
May	85°	29°	49.8°	5.64	......	10	9	12	13	W.
June	86°	39°	60.7°	2.95	......	14	11	5	7	W.
Total	......	......	......	48.01	63	136	114	115	120	......
Mean	73.2°	22.5°	46.5°	......	......	......	......	......	......	......

SUMMARY, JANUARY 1, 1890, TO JUNE 30, 1907, INCLUSIVE.

	Maximum Temperature.	Minimum Temperature.	Mean Temperature.	Number of Clear Days.	Partly Cloudy Days.	Cloudy Days.	Days with .01 inch or more of Precipitation.	Total Precipitation, inches.
1890	91°	3°	48.3°	99	143	123	120	59.25
1891	94°	5°	49.4°	116	154	95	83	49.88
1892	92°	—1°	47.8°	147	116	103	89	42.56
1893	92°	—6°	46.5°	126	130	109	131	57.33
1894	93°	—9°	48.6°	110	130	125	114	48.19
1895	93°	—7°	48.2°	128	114	123	108	49.28
1896	93°	—11°	47.7°	131	112	123	109	49.87
1897	90°	—1°	48.3°	129	126	110	128	54.25
1898	95°	—4°	48.8°	110	114	141	131	72.21
1899, Jan. 1, to June 30	95°	—10°	42.1°	77	44	60	59	26.79
July 1, 1899, to June 30, 1900	90°	—5°	48.3°	141	113	111	102	51.67
July 1, 1900, to June 30, 1901	97°	—9°	48.4°	134	97	134	114	48.47
July 1, 1901, to June 30, 1902	93°	—1°	48°	138	116	111	109	53.14
July 1, 1902, to June 30, 1903	90°	—12°	48.3°	138	96	131	103	59.27
July 1, 1903, to June 30, 1904	93°	—16°	45.7°	156	107	103	118	50.06
July 1, 1904, to June 30, 1905	87°	—4°	45.3°	151	122	92	99	41.64
July 1, 1905, to June 30, 1906	92°	—3°	48.4°	175	99	91	97	53.57
July 1, 1906, to June 30, 1907	90°	—9°	46.5°	136	114	115	120	48.01

Average temperature, 17½ years, 48.8°. Average precipitation, 17½ years, 52.31 inches

REPORT OF THE TREASURER.

THE RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, *in account with the* UNITED STATES APPROPRIATION, 1906–1907.

1907.	DR.		
	To receipts from the treasurer of the United States as per appropriation for fiscal year ended June 30, 1907, as per act of Congress approved March 2, 1887		$15,000 00
1907.	CR.		
	By Salaries	$8,484 77	
	Labor	2,493 73	
	Publications	47 99	
	Postage and stationery	226 62	
	Freight and express	113 05	
	Heat, light, water, and power	486 23	
	Chemical supplies	10 31	
	Seeds, plants, and sundry supplies	375 85	
	Fertilizers	157 43	
	Feeding stuffs	709 34	
	Library	43 29	
	Tools, implements, and machinery	177 49	
	Furniture and fixtures	527 22	
	Scientific apparatus	21 42	
	Live stock	2 00	
	Traveling expenses	399 99	
	Contingent expenses	15 00	
	Buildings and land	708 27	
			$15,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Rhode Island

Agricultural Experiment Station for the fiscal year ended June 30, 1907; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $15,000, and the corresponding disbursements $15,000, for all of which proper vouchers are on file, and have been examined by us and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress approved March 2, 1887.

CHARLES DEAN KIMBALL,
R. S. BURLINGAME,
Auditors.

THE RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, *in account with the* UNITED STATES APPROPRIATION, 1906–1907.

1907. DR.

To balance on hand		$2,535 80
Receipts from the treasurer of the United States as per appropriation for fiscal year ended June 30, 1907, as per act of Congress approved March 16, 1906		4,464 20
		$7,000 00

1907. CR.

By Salaries	$4,686 03	
Labor	720 00	
Postage and stationery	0 88	
Freight and express	1 34	
Heat, light, water, and power	45 50	
Chemical supplies	39 82	
Seeds, plants, and sundry supplies	118 45	
Fertilizers	60 82	
Feeding-stuffs	288 41	
Library	507 09	
Tools, implements, and machinery	17 70	
Scientific apparatus	178 05	
Live stock	181 50	
Traveling expenses	154 41	
		$7,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Rhode Island Agricultural Experiment Station for the fiscal year ended June 30, 1907; that we have found the same well kept and classified as above, and that the balance on hand was $2,535.80 and the receipts for the year from the treasurer of the United States are shown to have been $4,464.20, and the corresponding disbursements $7,000.00; for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress approved March 16, 1906.

CHARLES DEAN KIMBALL,
R. S. BURLINGAME,
Auditors.

C. H. Coggeshall, *Treasurer, in account with the* Rhode Island Agricultural Experiment Station, *for the year ended June* 30, 1907.

1907.	Dr.		
	To Balance from last year	$3,721 63	
	Station receipts	1,001 06	
	Interest	155 21	
			$4,877 90
1907.	Cr.		
	By Postage and stationery	$11 55	
	Seeds, plants, and sundry supplies	15 36	
	Traveling expenses	2 25	
	Chemicals supplies	8 02	
	Feeding-stuffs	49 93	
	Live stock	260 00	
	Heat, light, water, and power	24 00	
	Scientific apparatus	11 88	
	Library	30 27	
	Tools, implements, and machinery	18 57	
	Freight and express	17 15	
	Labor	27 63	
	Contingent expenses	46 32	
	Buildings and land	407 03	
	Balance	3,947 94	
			$4,877 90

This certifies that we, the undersigned, auditing committee of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts, have examined the account of C. H. Coggeshall, treasurer of the Rhode Island Agricultural Experiment Station, and find the same correct.

The total receipts were $4,877.90, and the total expenditures were $929.26, thus leaving a balance to new account of $3,947.94.

CHARLES DEAN KIMBALL,
R. S. BURLINGAME,

Auditors.

EXCHANGES.

Agricultural Advertising, Pittsburg, Pa.
Agricultural Epitomist, Spencer, Ind.
Agricultural Gazette of New South Wales, Sydney, Australia.
Agricultural Ledger, Calcutta, India.
A Lavoura, Boletim de Sociedade Nacional de Agricultura, Rio de Janerio, Brazil.
American Cultivator, The, Boston, Mass.
American Farm World, Augusta, Maine.
American Fertilizer, The, Philadelphia, Pa.
American Hay, Flour, and Feed Journal, New York.
American Horse Breeder, Boston, New York, and Chicago.
American Fruit and Nut Journal, Petersburg, Va.
American Philosophical Society, Proceedings of the Society.
American Poultry Advocate, Syracuse, N. Y.
American Poultry Journal, Chicago, Ill.
American Sheep Breeder and Wool Grower, Chicago, Ill.
American Stock Farm, The, Winona, Minn.
American Stock Keeper, Boston, Mass.
American Sugar Industry and Beet Sugar Gazette, Chicago, Ill.
Annales de Gembloux, Gembloux, Belgium.
Arboriculture, Connersville, Ind.
Better Fruit, Hood River, Oregon.
Boletim da Agricultura, Saõ Paulo, Brazil.
Boletim de Museu Goeldi, Para, Brazil.
Boletín del Ministerio de Agricultura, Buenos Aires, South America.
Boletín Oficial de la Secretaria de Agricultura, Havana, Cuba.
Breeder's Gazette, Chicago, Ill.

Bulletins of the Botanical Department of Jamaica, and Reports of Public Gardens and Plantations.
Bulletins of the Hygienic Laboratory, Treasury Department, Washington, D. C.
Bulletins of the New York State Museum.
Chicago Daily Drover's Journal, Chicago, Ill.
Colman's Rural World, St. Louis, Mo.
Connecticut Farmer, New Haven, Conn.
Cotton Seed, The, Atlanta, Ga.
Elgin Dairy Report, Elgin, Ill.
Evening Tribune, Providence, R. I.
Farm and Live Stock Journal, Detroit, Mich.
Farm and Stock, St. Joseph, Mo.
Farming, New York City.
Farm Journal, Philadelphia, Pa.
Farm Life, Chicago, Ill.
Farm Poultry, Boston, Mass.
Farm Press, Chicago, Ill.
Farm Progress, St. Louis, Mo.
Farm, Stock, and Home, Minneapolis, Minn.
Farmers' Advocate, London, Ontario, and Winnipeg, Manitoba.
Farmers' Guide, Huntington, Ind.
Farmers' Review, The, Chicago, Ill.
Feather, The, Washington, D. C.
Feathered World, The, London, England.
Flour and Feed, Waukegan, Ill.
Fruit Grower, The, St. Joseph, Mo.
Garden Magazine, The, New York City.
Geflügel-Züchter, Hamburg, Wis.
Hoard's Dairyman, Fort Atkinson, Wis.
Holstein-Fresian Register, Brattleboro, Vt.
Homestead, The, Des Moines, Iowa.
Hospodárské Listy, Chicago, Ill.
Illuminated World Life, Minneapolis, Minn.

Indiana Farmer, Indianapolis, Ind.
Industrious Hen, The, Knoxville, Tenn.
Journal Royal Horticultural Society, London, England.
Journal Board of Agriculture, London, England.
Journal of Department of Agriculture, Perth, Western Australia.
Kansas Farmer, Topeka, Kansas.
Kimball's Dairy Farm, Waterloo, Iowa.
Maryland Agricultural Quarterly, College Park, Md.
Metropolitan and Rural Home, The, New York City.
Michigan Farmer, The, Detroit, Mich.
Miscellaneous Publications, Department of Agriculture and Mines, Natal, Africa.
Modern Farmer and Busy Bee, The, St. Joseph, Mo.
Minnesota and Dakota Farmer, Brookings, S. D.
Missouri Agricultural College Farmer, Columbia, Mo.
National Stockman and Farmer, Pittsburg, Pa.
Nebraska Farmer, Omaha, Neb.
New England Farmer, Brattleboro, Vt.
New England Homestead, Springfield, Mass.
New Zealand Dairyman, The, Wellington, N. Z.
New Hampshire Farmer and Weekly Union, Manchester, N. H.
Northwest Horticulturist, The, Tacoma and Seattle, Wash.
Nut Grower, The, Poulan, Ga.
O Criador Paulista, Saõ Paulo, Brazil.
Ohio Farmer, Cleveland, Ohio.
Oregon Agriculturist, Portland, Oregon.
Orff's Farm and Poultry Review, St. Louis, Mo.
Pacific Dairy Review, The, San Francisco, Cal.
Pigeons, Peotone, Ill.
Poultry, Peotone, Ill.
Poultry Gazette, Kansas City, Kansas.
Poultry Herald, St. Paul, Minn.
Poultry Husbandry, Waterville, N. Y.
Poultry Keeper, The, Quincy, Ill.

Poultry Success, Des Moines, Iowa.
Poultry Topics, Lincoln, Neb.
Practical Farmer, The, Philadelphia, Pa.
Prairie Farmer, The, Chicago, Ill.
Publications of Agricultural Research Institute, Pusa, India.
Publications of Armstrong College, New Castle-upon-Tyne, England.
Publications of Department of Agriculture of Victoria, Melbourne, Australia.
Publications of Department of Agriculture, Ontario and Ottawa, Canada.
Publications of Department of Agriculture, Tallahassee, Florida.
Publications of Department of Agriculture, Atlanta, Ga.
Publications of Department of Agriculture, Mysore State, India.
Publications of Department of Agriculture, Wellington, New Zealland.
Publications of Department of Agriculture, Harrisburg, Pa.
Publications of Entologizka Foreningen, Stockholm, Sweden.
Publications of Estación Agricola Experimental de Ciudad Juáres, Chihuahua, Mexico.
Publications of Hawaiian Sugar Planters' Association, Honolulu, H. T.
Publications of Imperial Agricultural Experiment Station, Nishgahara, Tokyo, Japan.
Publications of Smithsonian Institution, Washington, D. C.
Publications of State Board of Agriculture, Augusta, Maine.
Publications of State Board of Agriculture, Boston, Mass.
Publications of State Board of Agriculture, Raleigh, N. C.
Publications of State Board of Agriculture, Columbus, Ohio.
Publications of State Board of Agriculture, Providence, R. I.
Publications of State Board of Entomology, Atlanta, Ga.
Publications of State Board of Health, Concord, N. H.
Publications of University College, Bangor, North Wales.
Rakings, York, England.
Reliable Poultry Journal, Quincy, Ill.

Republic, The, St. Louis, Mo.
Rock Products, Louisville, Ky.
Rural New Yorker, New York City.
Rural World, London, England.
Skandinavisk Farmer Journal, Minneapolis, Minn.
Southern Farm Magazine, Baltimore, Md.
Southern Fruit Grower, The, Chattanooga, Tenn.
Southern Planter, Richmond, Va.
Successful Poultry Journal, Chicago, Ill.
Texas Farmer, Dallas, Texas.
The Strawberry, Three Rivers, Mich.
Town and Country Journal, San Francisco, Cal.
Up-to-Date Farming and Gardening, Indianapolis, Ind.
Wallace's Farmer, Des Moines, Iowa.
Western Fruit Grower, St. Joseph, Mo.
W. Weddel & Co.'s Colonial Dairy Produce Report, London, England.
Wilson Bulletins, Wilson Ornithological Club, Oberlin, Ohio.
Wisconsin Agriculturist, Racine, Wis.
Year Books, and current publications of the Deutschen Landwirtschafts-Gesellschaft.

Directions for Binding the Bulletins and Reports of the Rhode Island Experiment Station.

Vol.	1-3,*	Bulletins	1-9,	Reports,	1-3,	1888-1890.
"	4,	"	10-14,	Report,	4,	1891.
"	5,	"	15-20,	"	5,	1892.
"	6,	"	21-26,	"	6,	1893.
"	7,	"	27-30,	"	7,	1894.
"	8,	"	31-35,	"	8,	1895.
"	9,	"	36-42,	"	9,	1896.
"	10,	"	43-46,	"	10,	1897.
"	11,	"	47-51,	"	11,	1898.
"	12,	"	52-55,	"	12,	1899.
"	13,	"	56-69,	"	13,	1899-1900.
"	14,	"	70-78,	"	14,	1900-1901.
"	15,	"	79-86,	"	15,	1901-1902.
"	16,	"	87-94,	"	16,	1902-1903.
"	17,	"	95-101,	"	17,	1903-1904.
"	18,	"	102-107,	"	18,	1904-1905.
"	19,	"	108-114,	"	19,	1905-1906.
"	20,	"	115-122,	"	20,	1906-1907.

*Vols. 1-3 in one cover. Beginning with volume 4, a title page and index for each volume is to be found at the end of the annual report for each year. The year covered by a volume formerly was the calendar year, but now it extends from July 1 to June 30. Each volume, beginning with volume 4, is paged separately. The Bulletins of a given year precede the Report, and the latter is paged in continuation of the last Bulletin belonging in the volume.

BULLETINS

AND

ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDED JUNE 30,

1907.

PROVIDENCE.
E. L. FREEMAN COMPANY, STATE PRINTERS,
1908.

INDEX

OF THE

BULLETINS AND ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDED JUNE 30, 1907.

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Rhode Island

Report
Agricultural Experiment Station,

Year Ended June 30,

1908

PART II
TWENTY-FIRST ANNUAL
REPORT OF THE STATION.

FORMAL REPORT OF
THE BOARD OF MANAGERS
IS PART I.

COLLEGE CATALOGUE
IS PART III.

Kingston,
R. I.

State of Rhode Island and Providence Plantations.

TWENTY-FIRST ANNUAL REPORT

OF THE

RHODE ISLAND

AGRICULTURAL EXPERIMENT STATION,

1907-1908.

PART II.

OF THE

TWENTY-FIRST ANNUAL REPORT

OF THE

CORPORATION, BOARD OF MANAGERS

OF THE

Rhode Island College of Agriculture and Mechanic Arts,

MADE TO THE

GENERAL ASSEMBLY AT ITS JANUARY SESSION, 1909.

[PARTS I. AND III. OF THIS REPORT — REPORT OF PRESIDENT AND BOARD OF MANAGERS AND COLLEGE CATALOGUE — ARE PRINTED UNDER SEPARATE COVERS.]

PROVIDENCE, R. I.
E. L. FREEMAN COMPANY, PRINTERS TO THE STATE.
1908.

The Station.

BOARD OF MANAGERS

OF THE

RHODE ISLAND

College of Agriculture and Mechanic Arts.

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LEON J. COLE,† Ph. D.	Animal Breeding and Pathology.
GEORGE E. ADAMS, B. Sc.	Horticulture; Associate, Agronomy.
W. F. KIRKPATRICK,‡ B. Agr., B. E.	Asst., Animal Breeding and Pathology.
W. F. SCHOPPE, B. Sc.	Assistant, Animal Feeding.
P. H. WESSELS, B. Sc.	Assistant, Chemistry.
F. R. PEMBER, M. Sc.	Assistant, Plant Physiology.
S. C. DAMON, B. Sc.	Assistant, Agronomy.

OTHER MEMBERS OF THE STATION STAFF.

J. FRANK MORGAN, M. A.	Assistant, Chemistry.
L. F. WHIPPLE	Assistant, Chemistry.
WILHELM B. QUANTZ, Ph. D.	Assistant, Chemistry.
E. A. MALLETTE	Assistant, Floriculture.
NATHANIEL HELME	Meteorology.
GRACE E. HOVEY, B. Sc.	Stenographer and Accountant.
E. ELIZABETH MEEARS	Stenographer and Librarian.

The publications of the Station will be mailed free, upon request, to all residents of Rhode Island to whom they are of interest. Suggestions as to how the station can aid the state are gladly received. Visitors are always welcome. Railway station, telegraph, express, and post-office—Kingston, Rhode Island. Long distance telephone, Narragansett Pier Exchange.

*In charge of experiments in plant physiology.
†Expert in the Bureau of Animal Industry, U. S. Department of Agriculture. Engaged in coöperative work between the Bureau and Station.
‡Agent, Bureau of Animal Industry, U. S. Department of Agriculture. Engaged in coöperative work between the Bureau and the Station.

LETTER OF TRANSMITTAL.

To His Excellency, Aram J. Pothier, Governor, and the Honorable the General Assembly of the State of Rhode Island, at its January Session, 1909.

KINGSTON, R. I., January 5, 1909.

I have the pleasure to present herewith, in compliance with the statute of the State and the Congressional acts of March 2, 1887, and March 16, 1906, the Report of the Director of the Rhode Island Agricultural Experiment Station for the year ended June 30, 1908.

Respectfully submitted,

For the Board of Managers,

CHARLES DEAN KIMBALL,

President.

AGRICULTURAL EXPERIMENT STATION

OF THE

RHODE ISLAND COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

KINGSTON, R. I., June 30, 1908.

HON. CHARLES DEAN KIMBALL,

President, Board of Managers.

SIR:—I have the honor to transmit herewith the Twenty-first Annual Report of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1908.

Respectfully yours,

HOWARD EDWARDS,

President.

DIRECTOR'S REPORT.

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DIRECTOR'S REPORT.

REPORT OF THE DIRECTOR.

H. J. Wheeler.

To Howard Edwards, President.

Sir:—The work of the Experiment Station for the past year is presented under the following headings:

Division of Horticulture.

The charge of this division of the Station was transferred, at the beginning of the year, to Prof. G. E. Adams. The chief work of the past year has been the continuance of the experiments already inaugurated by Prof. F. W. Card, as follows:

(1) Breeding and selection experiments with sweet corn.

(2) Breeding experiments with raspberries for the purpose of producing, if possible, an extra early variety of good quality.

(3) Breeding experiments with strawberries for the purpose of producing an extra late variety of good market quality.

(4) An experiment in rotating market garden crops both with and without the aid of stable manure.

(5) An experiment to study the value of different grass mixtures for polo grounds, golf links, and lawns; and to ascertain the influence of basic, neutral, and acidic manures upon the relative permanence of different grasses and weeds.

A few other minor experiments, which were begun at an earlier date, are also in progress.

The interpollination experiment with blackberries and the experiments with clovers have been necessarily discontinued.

An important new feature of the Horticultural Department is the experimental work which has been begun by Professor Adams, with carnations and roses. The object of this work is to study the effect of various substances upon the physical condition of greenhouse soil and the effect of the resulting conditions upon the growth and blooming of the plants. At the same time it is planned to study the effect of various combinations of chemical manures, used in comparison with stable manure. It is hoped that as a result of this work some hints may be secured as to the best treatment of greenhouse soils for the purpose of avoiding their frequent renewal, which is fraught with great expense.

DIVISION OF CHEMISTRY.

In the course of the year, upon recommendation of the Station Director, Doctor Hartwell, previously associate chemist, was appointed chemist.

The analytical and police work of the division for the year has embraced the inspection of fertilizers and cattle foods, carried on under State laws, together with the analysis of fertilizers and other materials for other divisions of the Station.

The division is continuing the study of the influence of sodium and potassium salts upon the growth of plants, and upon the composition of the plants produced by their aid.

The study of the efficiency of the paraffined wire-basket method for ascertaining the needs of soils has been completed.

The investigation for the purpose of ascertaining if the percentage of phosphoric acid found in the dry matter of the flat turnip is a true indication of the phosphorus requirements of the soil on which it is grown, are being continued whenever opportunity is afforded.

The study is being continued of the relative efficiency of various organic nitrogenous manures.

In connection with the field experiments, work is in progress, by way of analyses and pot-culture experiments, to aid in throwing light upon the cause of the beneficial influence of liming upon the growth

of certain plants and of the greatly different growth of a given plant as affected by the variety of plant which has preceded it. This work is being conducted in coöperation with the Division of Agronomy.

Certain results of the work of this division may be found in the subsequent pages of this report.

DIVISION OF ANIMAL BREEDING AND PATHOLOGY.

In the course of the past fiscal year the chief of the division, Dr. L. J. Cole, resigned to accept a position at the Sheffield Scientific School, Yale University. Arrangements were, however, perfected by which he should retain the direction of the work at this Station until July 1, 1908. This was accomplished by frequent visits to Kingston during the remainder of the year.

In consequence of the resignation of Doctor Cole, the position of biologist has been created, which has been filled by the appointment of Dr. Philip B. Hadley, of Brown University. Doctor Hadley is to assume his duties on July 1, 1908. Owing to the partial absence of Doctor Cole, unusual responsibility was thrown upon Mr. Kirkpatrick, who has merited particular commendation for the manner in which he has attended to his various duties.

The division has continued the study of the cause of the blackhead disease of turkeys, involving the possibility of its control.

Certain observations have also been made on conditions affecting incubation.

Breeding experiments have been in progress during the year with pigeons for the purpose of ascertaining if any definite order of sex sequence exists and for the purpose of learning what characteristics do or do not follow the Mendelian law, also for the purpose of discovering any new laws bearing upon the subject of breeding.

In the course of the year this division has been coöperating with the Division of Chemistry in the conduct of feeding experiments with chicks.

It has been deemed wise to expand the work of the division to cover still other diseases of poultry, which will be studied from time to time as the opportunity presents itself.

DIVISION OF ANIMAL FEEDING.

Owing to the resignation of Mr. J. W. Bolté, in the course of the year, the work of this division, which was created as a temporary expedient, has been transferred to the divisions of chemistry and biology.

The nature of the problems involved in the kind of work which ought to be done is such that it should be placed in the immediate charge of those familiar with the various chemical and physiological features and in the hands of those experienced in the conduct of agricultural research. It is hoped that this arrangement for co-operation will prove more satisfactory and will result in research work of a higher order in the line of animal feeding than could otherwise have been possible.

DIVISION OF AGRONOMY.

The Division of Agronomy is continuing the studies in grass culture in the attempt to find the most efficient and economical manures for top-dressing grass-land.

The experiments for determining the lime requirements of plants are still being continued.

There are in the State many thousands of acres of land that are not returning enough to cover the taxes and a fair interest on the cost. Sufficient stable manure for the renovation of such land is unobtainable, and, even if it were, would be prohibitive on account of the cost of transportation. Under such circumstances it seemed important to ascertain if it were possible to renovate, and maintain such soils in a high state of fertility, at a profit, by the use of chemical manures. To this end seven different systems of crop rotation and manuring are being compared, the financial results of which are,

in certain cases, highly encouraging. Bulletins relating to certain of these rotations have been published, and others will be issued from time to time.

The study of the efficiency of the phosphoric acid of Peruvian guano, as compared with that in acid phosphate, bone meal, and basic slag meal (Thomas phosphate), is being continued with a variety of crops.

The study of the relative efficiency of nine different phosphatic manures, for miscellaneous farm crops, has already shown that the roasted iron and aluminum phosphate (roasted redondite), which by chemical analysis appears to have great value, may be almost valueless for certain crops on unlimed land; yet for other crops, on limed land, it may be quite efficient. Valuable results are also being secured bearing upon the agricultural value of the phosphoric acid of bone meal, basic slag meal, and floats, showing that the last-mentioned phosphate is far less efficient for most crops than bone meal or basic slag meal.

The results show that for immediate effects, where phosphoric acid is greatly deficient, nothing equals the soluble phosphates (acid phosphate, dissolved bone-black, and dissolved bone), and that the basic slag meal is quicker in its action than bone meal; in fact, the former approaches the soluble phosphates very closely in this particular. For immediate results the bone meal is much better than floats, though inferior to basic slag meal.

The experiments with sodium salts are being continued for the purpose of learning what varieties of plants are most likely to be benefited by them when postassium salts are lacking. Crops are being secured for analysis in order to see if sodium has exerted an injurious or beneficial effect upon the organic constituents of the plants. In the same connection observations are being made concerning the relative susceptibility of potato plants to blight, as affected by the varying amounts of potassium and sodium present in the manures. Furthermore, experiments are being conducted to

see if potatoes, grown for two or more generations where there is a deficiency of potassium, show weakened vitality.

Experiments are in progress to determine what degree of financial advantage arises from sowing rye, crimson clover, or other legumes as a catch crop between Indian corn at the last cultivation.

An interesting problem from a financial standpoint is the experiment in progress for the purpose of learning if one or two good crops of Indian corn cannot be secured, without manuring, on land which has been top-dressed regularly for the production of grass. The crop of 1907 was so good that another is being grown on the same land in 1908; the outlook for which is now most promising. If it is found that hay can be produced at a handsome profit by employing annual top-dressings of chemical manures, and that the decaying residues of the extensive grass roots induced by the top-dressing will then furnish the food (supplementd with that naturally in the soil) for the production of two good corn crops, the importance of top-dressing, instead of leaving grass-lands to themselves, will be much emphasized.

The trial of varieties of flint Indian corn in coöperation with the U. S. Department of Agriculture is being continued in order to see if the introduction of varieties from other parts of the country will be profitable.

The experiment with several hundred varieties of potato tubers is still in progress for the purpose of learning which are reasonably resistant to the blights, and for their utilization, if desirable, in the attempt to breed blight-resistant varieties possessed of the other qualities which the Rhode Island market demands. No progress was made in this selective work in 1907 on account of the almost entire absence of blight during that season.

Improvements.

During the year the old calculating and mailing machines have been exchanged for new and improved ones.

Additional shelves have been erected in the attic for the storage

of various materials, in order that they may be arranged systematically and may be made instantly accessible.

The walls and floors of the main Station building have been renovated. Many minor improvements have been made to the poultry plant, including the erection of a chimney for the brooder house.

A case for the storage of culture tubes has been added to the equipment of the biological laboratory.

The old pot-culture house, which was greatly in need of renovation, has been reglazed, painted, and generally repaired. The tracks connected with the house have been put in repair, and the outside pot enclosure has been painted.

The library facilities have been enlarged by the addition of a new, double, six-section stack.

NEEDS OF THE STATION.

Attention should be called, again, to the increased opportunity for soil and greenhouse investigations which would be afforded if provision were made for supplying heat in the pot-culture house during the winter.

The need of more satisfactory office facilities for the Director has been pointed out in previous reports, and this necessity increases with each successive year.

In previous reports attention has been called to the need of a fireproof storage house for samples of material accumulated in connection with the work of investigation, and also of a dry and fireproof storage vault for the records of the experimental work. In view of the liberal federal appropriation to the Station, it is important that the State should furnish a safe storage place for the records without delay.

Attention has been called, previously, to the importance of experiments in orchard culture, and to the fact that these are impossible unless additional areas of land are placed at the disposal of the Station, either through assignment from the College farm or

by purchase. In fact, with each year the College land is becoming less suited to such experiments on account of its increasing fertility and owing to the irregularities introduced by subdivision of the fields into sections used for different purposes.

One of the greatest immediate needs of the Station is a long poultry house where feeding experiments with hens can be conducted and where a sufficient number of fowl can be maintained to supply eggs for the production of chicks of uniform character. Such chicks are necessary for use in the work in chicken feeding. In this connection the Station is studying the relative value of various concentrated feeding-stuffs, and is endeavoring to ascertain to what the differences in efficiency are due, and how the efficiency of certain feeds can be increased. In view of the liberal treatment accorded the Station by the federal government, it would seem that the State should furnish some of these facilities which are so sorely needed at this time, especially in view of the fact that Rhode Island makes no annual appropriation for the maintenance of the Station, such as is made in many of the other States.

An equally great, or even more pressing need is a small hospital building for use in connection with the study of poultry diseases, since at the present time the Station is entirely without facilities in this line. In fact both buildings are essential to making the best use of the funds which the federal government is supplying for maintenance of the work of investigation.

Coöperative Work.

After July 1, 1908, the Station will be engaged in coöperative work with the U. S. Department of Agriculture only to the extent of making trials of flint corn (maize) in coöperation with the Bureau of Plant Industry.

The coöperation of the Bureau of Soils in testing the efficiency of the paraffined wire-basket method for ascertaining the needs of soils, a method devised by the bureau, was withdrawn on account of

a reduced appropriation and the increased demands upon the bureau. Nevertheless, since the results of the previous year had shown that where the soil deficiencies were not great the method often failed to give satisfactory results, it was decided to continue the work, even without further aid from the bureau, in order to determine definitely, if possible, if the method would give as reliable indications under normal soil conditions as it was found to give when only such soils were studied as had been exhausted by one-sided manuring through a long series of years.

On February 6, 1908, notification of the withdrawal of coöperation on the part of the Bureau of Animal Industry was given, to take effect at the end of the fiscal year (June 30, 1908). In this letter the chief of the bureau, in speaking of the chief of the Division of Pathology and his work in the bureau on blackhead (which was of recent origin), stated that "Through an unforeseen accident he was unable last year to connect these investigations with breeding work at the Bethesda Experiment Station. As both these lines bid fair at the present writing to work out well this coming year, it would appear to be almost superfluous for the Bureau to engage in further coöperative work on this line after July 1, 1908. Especially would coöperation be of doubtful utility in view of the fact that the findings in the laboratory here do not appear to be in absolute accord with those of Dr. Cole and Mr. Hadley."

It should be stated that when this coöperation was entered upon the bureau was not engaged in a study of the blackhead disease and refused coöperation, except in turkey breeding as a means of controlling the disease. The Station had then been engaged for some time in the study of the etiological features of the "blackhead" disease.

Subsequently the bureau arbitrarily transferred the coöperation from its Division of Animal Husbandry to its Division of Pathology, leaving the Station no option, excepting withdrawal. The next step was the publication of a bulletin concerning the subject of "blackhead" disease. The only technical ground which might have been

claimed (but which was not advanced in the letter of February 6, 1908) for the withdrawal of coöperation was an inadvertent act of an employee of the Station for which the Director of the Station, who was the party to the contract, was not to blame and from which he was fully exonerated by the bureau.

Mention is made of the history of the coöperation to show that it may be of such limited tenure that an experiment station cannot look forward to undertaking important investigations with such uncertain prospect for continued support; and it seems probable that if really effective and successful coöperation is to be brought about between the experiment stations and the U. S. Department of Agriculture, such coöperation must come through a sympathetic channel, such as a special bureau, rather than through chiefs of bureaus, who may be looking for personal and bureaucratic aggrandizement in the same lines of research, and who may readily look upon the stations as rivals. The great field of agricultural research is far wider than the federal government and the individual States can hope to cover for years, and there is the broadest field of work for all. In such investigations there must be ample academic freedom and opportunity for individual initiative if the greatest progress is to be made, conditions which can be fulfilled if the work is properly organized and directed.

Changes in the Station Staff.

During the year there have been no changes in the horticultural staff of the Station, though with the beginning of the new fiscal year (July 1, 1908) Prof. G. E. Adams will devote himself chiefly to teaching in the College, retaining charge merely of the work in floriculture in the Station.

In consequence of the more complete withdrawal of Prof. Adams from Station work, the Director of the Station assumes the full supervision of the work in agronomy and the continuance of the outside work formerly conducted by the Horticultural Division. In order to render possible closer attention to the details of the work in

agronomy than formerly, and to permit of an increase in the volume of coöperative experiments among the farmers, the department of agronomy has been increased by the appointment of Albert L. Whiting, B. Sc., a graduate of the Massachusetts Agricultural College, as assistant agronomist.

The vacancy created by the resignation of Dr. L. J. Cole, to accept a position at Yale University, has been filled by the appointment of Philip B. Hadley, Ph. D., of Brown University.

In the spring of 1908 W. F. Schoppe, B. Sc., who was appointed, the preceding August, assistant in animal feeding, resigned to accept a position at the Agricultural College of Montana, and the vacancy created was filled by the appointment of J. Swett Irish, B. Sc., a graduate of the University of Maine.

In the Chemical Division the resignation of H. S. Hammond, B. S. A., who withdrew to accept a position at the Macdonald College in Canada, left a vacancy which was filled by the appointment of William Quantz, Ph. D.

Under a special arrangement Mr. J. W. Bolté was engaged to carry to completion such experimental work as he had in progress, but before its completion he resigned to enter upon a business career. The continuance of work of the same general character has been provided for by its assignment to the chief of the division of chemistry, who will continue it in coöperation with the chief of the Division of Biology.

Owing to the resignation of Miss Beulah A. Hoitt, as clerk and accountant, the vacancy was filled by the appointment of Miss Grace E. Hovey, B. Sc., a graduate of Simmons College.

The rapidly increasing demands for additional clerical assistance have been met by the appointment of Zilla M. Constable, B. Sc., a graduate of Simmons College, who will assist in the keeping of records, proof-reading, and in attending to the ever increasing correspondence.

PUBLICATIONS.

The following bulletins have been published in the course of the year:

No. 123, The Rearing and Management of Turkeys, with Special Reference to the Blackhead Disease, August, 1907, pp. 1–64.

No. 124, Further Experiments in Connection with the Blackhead Disease of Turkeys, November, 1907, pp. 65–106.

No. 125, Commercial Fertilizers, November, 1907, pp. 107–122.

No. 126, Feeding Experiments with Chickens, Cockerels, and Turkeys, January, 1908, pp. 123–150.

No. 127, Some Recent Feeding Experiments. Analyses of Commercial Feeding-stuffs, April, 1908, pp. 151–180.

No. 128, A Further Study of Soil Treatment in Greenhouse Culture, June, 1908, pp. 181–196.

No. 129, Experiments with Feldspathic Rock as a Source of Potassium, June, 1908, pp. 197–206.

CONCERNING WORK WHICH THE STATION CAN AND CANNOT UNDERTAKE.

There seems to be a more or less prevalent idea that, by virtue of being taxpayers, individuals citizens of the State may send samples of material to the Station for analysis, without charge. As a result, the Station is in frequent receipt of water, minerals, and materials of various kinds which are sent for examination. In the first place, the public does not appear to appreciate that the State makes no annual appropriation for the maintenance of the Experiment Station. This support is provided for entirely by appropriations made by the federal government. These federal appropriations are only available for specific purposes which are carefully outlined in the federal acts, and the appropriations are immediately withheld from the States if these conditions are violated. Furthermore, any misappropriations of these funds would have to be made good before further disbursements to the State would be made from the federal treasury under these acts.

On this account the Station cannot examine free; minerals, spring waters, well waters, commercial fertilizers sampled by farmers, or fertilizers or other materials sent by manufacturers and dealers; neither does the Station seek such work even for pay (the only condition under which it could be done), but prefers that such private work should be sent to commercial chemists who make it their business.

If any person knows of the sale in the State of any new feeding-stuff or fertilizer coming under the provisions of the fertilizer or feeding-stuff inspection laws, and will send the name of the goods and the name and address of the dealer to the Director of the Station, he will detail an official inspector to sample the goods. The samples will then be examined and reported upon without charge. Such expenses are met by the provisions of the State fertilizer and feeding-stuff inspection acts, but these funds cannot be drawn upon for the examination of any sample of material which Mr. A. or Mr. B. may draw and forward on his own account.

This course is in accordance with the law, and is the only one which can insure fair and proper sampling and prevent possible injustice to manufacturers or dealers against whom some unscrupulous party might have a grudge. All official samples taken by the Station representative are drawn in duplicate. Both are sealed at once, one being taken to Kingston and one left with the party selling or holding the goods. In case the Station analysis is doubted, or questioned in any way, the duplicate sample can be divided into three parts, in the presence of all of the parties in interest, one to be taken for analysis by each interested party, and one to be sent to any disinterested chemist upon whom the two may agree. In this way the duplicate sample serves as a protection against fraud or mistakes on either side.

If at any time any citizen of the State has ground to suspect that fertilizers or feeding-stuffs, coming under the provisions of the State law, are misbranded or adulterated, and will furnish all of the necessary information to the Station, the matter will be care-

fully investigated in connection with the regular work of inspection, and without charge.

Parties buying fertilizers or feeding-stuffs for their own use, free on board cars (f. o. b.) outside of the State, cannot have them examined here free of charge, since such goods do not come under the provisions of the State laws. Their only protection in such a case is that afforded by the laws in the State where the purchase is made. If such a purchaser has evidence of fraud in connection with such a purchase, and will report the facts to the Station, the matter will be brought to the attention of the proper official in the State where the purchase was made.

Factory wastes of agricultural value and natural deposits of fertilizing materials may be examined without charge, if the circumstances seem to warrant it, but then only under the condition that information concerning the process of manufacture, the source of the material, and any other desirable facts be furnished, so that the results may be published for the good of all citizens of the State.

It is hoped that the publication of this general statement may relieve the Station of a large amount of explanatory correspondence and of being made the recipient of a lot of miscellaneous material which could not be examined free without involving misappropriation of funds and the consequent withdrawal of the federal support from the Station. For the benefit of those not familiar with the situation, it should be stated that the United States Department of Agriculture sends a federal inspector to the Station annually, who not only goes over the experimental work in detail, but also examines carefully each individual bill and voucher, in order to see that no misapplication of funds results. By these means the funds of the Experiment Station are under the closest possible federal supervision.

The expenditures under each of the federal funds have to be scheduled monthly and yearly under about fifty subdivisions. Furthermore, exact records must be kept of the actual cost of each experiment or project carried on with the Adams Fund. In addition, there must be kept a record of the amount of salary received by each

employee from each State and federal account, all of which goes to show the amount of detailed work involved and the safeguards thrown about the expenditures, by the federal government, all of which is in addition to the auditing of the accounts by the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts.

ACKNOWLEDGMENTS.

The resignation of Dr. Cole to accept a position at Yale University was received with the utmost regret, and had it been possible he would have been retained at the Station. He possesses the rare faculty of planning experiments carefully and systematically, of giving proper attention to their execution, and of keeping splendid records of the work. It gives me pleasure to be able to speak of his work without reservation and in the very highest terms.

It is also a pleasure to mention in the most commendatory way the work of Prof. Adams, whose ability, energy, attention to the experimental work, and whose care in keeping the experimental records in the Divisions of Agronomy and Horticulture, have been invaluable to the Station.

It gives me particular satisfaction also to be able to report that Dr. Hartwell, who received during the year a flattering offer of a position in Delaware, was finally induced to remain in Rhode Island. He has been identified with the work of the Station practically since its beginning, and it would be a misfortune to have him withdraw. To all three of the gentlemen mentioned, and to the other members of the Station staff, all of whom have shown marked attention to their duties, and willingness to meet all unusual demands upon their time, I extend my hearty thanks.

Very respectfully submitted,

H. J. WHEELER,

Director.

DIVISION OF CHEMISTRY.

REPORT OF THE CHEMICAL DIVISION.

Burt L. Hartwell.

Effect of Sodium on Plant Composition.—During the past year determinations have been made of the proximate constituents of certain field crops which were manured with varying amounts of potassium and sodium, in chlorids and carbonates. Two crops of potatoes from certain of the plats have now been analyzed for starch, nitrogen, and ash. The crops from the plats receiving potassium without sodium were much larger than those from the reverse, but in tubers of the same size there was very little variation in the percentage of starch in dry matter. The percentage of nitrogen was larger in the tubers from the plats receiving only sodium than in those receiving only potassium; but the percentage of ash was less. The cooking quality did not differ so much as might have been expected, yet tubers of the same size from the potassium plats seemed slightly more mealy than those from the sodium plats. No positive difference was discernible in the cooking quality of tubers from the carbonate, and from the chlorid plats.

Results thus far obtained from a chemical examination of the beets indicate marked variations in the amount, and probably in the kind, of sugar in beets collected from the plats receiving different relative amounts of sodium and potassium.

Form of Phosphorus in Turnips.—Owing to the unusual drought in the summer of 1907, very few samples of crops were available from the coöperative soil tests in different parts of the State; and only a small amount of additional information was secured, there-

fore, regarding the relation between the amount of phosphorus in turnips and the amount of available phosphorus in soils. Some data have been secured which throw light on the solubility and reactions of the phosphorus in turnips. The phosphorus is largely soluble in water and in dilute acid. The greater part of the extracted phosphorus passes readily through parchment paper, and is precipitable by the ordinary reagents for inorganic phosphorus. We desire to ascertain whether any quantitative relation exists between this precipitable phosphorus and the amount of available phosphorus which is applied to or exists naturally in the soil.

Fertilizer Inspection.—The commercial fertilizers which were sold in 1907 were inspected as usual, and the analytical results may be found in Bulletins 122 and 125. One hundred and seven different brands of complete fertilizers, and about thirty samples of wood ashes, bones, manure salts, etc., were collected and analyzed.

Feeding-stuff Inspection.—During the fall of 1907 and winter of 1908 two hundred and twenty-three samples of commercial feeding stuffs were collected and analyzed, principally for protein and fat, in order to ascertain if these ingredients were present in accordance with the amounts which were guaranteed. The analytical results were published in Bulletin 127. In the same bulletin there was a compilation of brief abstracts of feeding experiments with farm animals, which had been recorded in recent bulletins and reports from different parts of the country.

Availability of Nitrogenous Manures.—The experiment to ascertain the amount of nitrogen which plants can obtain from different nitrogenous materials has been conducted for a number of years in sixty-three pots set in the ground. Two amounts of nitrogen, one fifty per cent. greater than the other, have been added each year to different groups of pots. Usually the larger application has not resulted in a larger crop, but in a more nitrogenous one. For this reason it becomes necessary to determine the amount of nitrogen in the crops which are grown from year to year, as greater differences have been shown in the amounts of nitrogen removed than in the size of the crops.

The present high price of nitrogen has led to the introduction into commercial fertilizers of many sources of this element which were originally considered to be of too low a grade for this purpose. Some of these nitrogenous materials are being tested, by growing plants in pots, for their value as sources of nitrogen in comparison with dried blood and nitrate of soda. Among the materials being tested are "patented nitrogenous potash sulfocyanide manure," "hide and skin meal," "original nitrogenous manure," and "tartar-yeast manure." As a result of two tests, the "original nitrogenous manure" has produced the largest crop, and yet the increase was only about one-half that with dried blood, and even less as compared with that from nitrate of soda. Certain of these materials scarcely increased the crops at all, but it remains to be seen whether they have made the crops more nitrogenous.

Nitrogen-Gathering Value of Legumes.—The pot experiment which was begun in 1906 with four different legumes, to determine the amount of nitrogen which would be collected from the air in a series of years, has been conducted thus far by growing the four legumes each summer in their respective pots and removing the crop. Later, winter vetch is grown in all of the pots, in the greenhouse, and is turned into the soil in the spring preparatory to planting the four legumes. In the summer of 1908 the legumes were making a satisfactory growth, although they were the fifth crop without any application of nitrogenous manures. The soy bean and cowpea make a particularly good growth and contain a large amount of protein.

The average amount of nitrogen removed in ten of these mature plants, without the roots, has been about two grams. These crops have been repeatedly grown in the field experiments of the Station, and deserve more attention than they are receiving from Rhode Island farmers.

Soil Tests with Seedlings.—The experiments with the wire-basket method of the U. S. Bureau of Soils, for determining the manurial requirements of soils, have been concluded. The results in continuation of those recorded in Bulletin 120 may be found in Bulletin 131.

The many instances of disagreement between the results by the basket and those secured in actual field practice rendered unreliable many of the indications which the method afforded.

Potassium from Feldspar.—The solution and pot experiments with finely-ground feldspathic rock have been concluded, and the results published in Bulletin 129. Tests with millet, beans, and wheat showed that the farmer cannot afford even to experiment with this material; for the crops were scarcely any larger than where no potassium was used.

Sodium as a Supplement to Potassium.—The work by means of water-cultures, which was designed to prove whether sodium is directly useful to plants or not, has shown that, with an insufficiency of potassium, sodium is directly useful. The first part of the work, which was carried on principally with wheat seedlings, appeared in the last annual report. The remainder is comprised in the succeeding paper. Other cereal seedlings were found to be benefited by sodium under conditions analogous to those which existed with the wheat, and the benefit was likewise shown to persist in the case of plants which were grown for four months in solution.

The question of the practical value of the sodium in nitrate of soda and in kainit is still being considered with the help of pot experiments.

Effect of Acid and of Ferrous Sulfate on Seedlings.—The field experiments have shown that different kinds of plants are very differently affected by a soil which turns a blue litmus paper red. Among the cereals, for example, the addition of alkaline material to such a soil is much more necessary for barley than for rye. A maximum crop of rye may be obtained without any addition of lime, whereas the growth of barley under the same conditions may be increased 200 per cent. The seedlings of these two cereals, and to a less extent those of wheat and oats, have been tested by growing them in nutrient solutions containing varying amounts of certain acids, and ferrous sulfate, to see if they are affected in the same relative way as they are by the field conditions. The effect of acids was recorded in the

last annual report. The effect of ferrous sulfate may be seen by consulting an article which appears upon subsequent pages of the present volume. It may be said, in brief, that no evidence was secured that rye was any less susceptible than barley to the acids, and to ferrous sulfate.

Miscellaneous Analyses.—A large part of the analytical work of the year has been in connection with unfinished problems and will be published when the work is terminated, but a few miscellaneous analyses will now be recorded.

SLUDGE.

	Per cent. I.	II.	III.
Water	8.13	16.30	0.26
Nitrogen	1.36	1.38	....
Phosphoric acid (P_2O_5)	0.96	3.41	1.70

Sludge is the precipitated material which is obtained when sewage is treated with lime, supplemented in some cases with iron or aluminum sulfate. The flocculent precipitate, consisting in part of phosphates, which forms upon the addition of lime to sewage contained in a settling tank, carries down not only the insoluble suspended matter of the sewage, but, to some extent, nitrogen and phosphorus in combination with organic matter. The material has some value as a manure, and when the cost of application is small it may be used economically under certain conditions.

Sample I was ordinary sludge. Sample II was a sludge said to have been treated in such a way as to increase its manurial value; when in the same state of dryness as sample I it contained a little more nitrogen and about four times as much phosphorus. Sample III was the ashes of sludge. In the process of burning, the nitrogen is volatilized. None of the samples contained significant amounts of potassium. These samples were sent by the city of Providence.

WOOL DUST.

	Per cent I.	II
Nitrogen	1.00	4.38

Wool dust or waste is of value for manurial purposes principally because of the nitrogen which it contains. The amount of this element is quite variable, and commonly equals between two and seven per cent. The nitrogen is usually not more than one-third as available during the first year as that in nitrate of soda. Samples of Rhode Island wool waste which have been examined here have usually contained about one-fourth of a per cent. of phosphoric acid and from three-fourths to three per cent. of potassium oxid.

I. DRIED BLOOD.
II. DISSOLVED BONE.
III and IV. GROUND BONE.

	Per cent. I.	II.	III.	IV.
Nitrogen	11.28	1.70	3.38	3.88
Phosphoric acid	1.72	14.81	19.56	19.86

Dried blood frequently contains so much phosphorus as to seriously interfere with its use in experiments in which it is desired to eliminate this element. This is sometimes due to an admixture of bone; but a sample of pure, dried, pig's blood was found to contain three-fourths of a per cent. of phosphoric acid.

I. SULFATE OF AMMONIA.
II. NITRATE OF SODA.

	Per cent. I.	II.
Nitrogen	20.89	15.32

POTASSIUM NITRATE.

	Per cent.
Water	0.23
Nitrogen	11.88
Potassium oxid	46.34
Chlorin	5.40

This material can frequently be purchased at a price which makes it the cheapest source of soluble nitrogen and potassium.

I. HIGH GRADE SULFATE OF POTASH.
II. HIGH GRADE MURIATE OF POTASH.
III. MURIATE OF POTASH.
IV. CARBONATE OF POTASH.

	Per cent.			
	I.	II.	III.	IV.
Potassium oxid	48.94	61.93	49.11	57.56

I. COMMON SALT.
II. SODIUM CARBONATE.

	Per cent.	
	I.	II.
Sodium oxid	51.80	55.39

GROUND LIMESTONE.

	Per cent.
Calcium oxid	50.23
Magnesium oxid	.05

In some parts of the country, finely-ground limestone is used for agricultural purposes in the place of slaked lime. It acts somewhat more slowly than the latter, which is an advantage in some instances. It is only recently that limestone has been ground in New England. The difference in the cost of transportation is a large factor in determining whether it is better economy to purchase the ground limestone, or the burnt lime which is prepared from the same and is slaked before using. The burnt lime, from which the carbon dioxid is driven out, is nearly all calcium oxid, and therefore contains about twice as much actual lime as the limestone.

Materials used in Feeding-Experiments with Chickens.

	Water.	Protein.	Ash.	Phosphoric acid.	Calcium oxid.
Cracked corn	14.03	8.56	1.16	0.52	0.07
Corn meal	13.59	8.56	1.39	0.61	0.05
Gluten feed	9.85	25.13	2.46	0.96	0.30
Linseed meal*	10.44	36.38	5.96	2.02	0.49
Alfalfa meal	10.26	12.38	8.46	0.39	1.71
Mixed feed	11.89	15.38	5.26	2.66	0.17
Granulated milk	9.10	43.50	20.13	5.85	9.82
Animal meal	6.84	38.88	38.90	14.31	18.40
Animal meal	......	43.81	......	13.30	18.23

*Contained 3.46 per cent. of ether extract.

Molasses.

		Per cent.
Water	Removed in 12 hrs. in boiling water oven	24.82
	Removed at about 70° temp. and 170 mm. pressure	23.85
Sucrose (cane sugar)		38.01
Reducing sugar, as invert sugar		19.51

SODIUM AS A PARTIAL SUBSTITUTE FOR POTASSIUM.

BURT L. HARTWELL AND F. R. PEMBER.

The present article is supplementary to one in the preceding annual report of this Station, to which reference should be made for a description of the method of growing seedlings in solution, the foundation nutrients in the solution, and other points which are not included here. Experimental work in the field, in pots, and in the laboratory, on the use of sodium in connection with potassium, is recorded in earlier publications of this Station.*

The solution work which was recorded in the last annual report was conducted with only wheat seedlings; and it was deemed important to ascertain whether the beneficial effects of sodium in connection with a deficient amount of potassium, which were noted with that plant, would probably be observable with other cereals. Accordingly, similar experiments were conducted with barley, oats, rye, and millet, the results of which will now be considered. The weights, in grams, secured with millet are given in table I.

TABLE I.

Effect of Sodium on Millet Seedlings.

Special Additions.	From Each Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
32 ppm. K. in K Cl........	120 121	5.92 5.78	100	100
8 ppm. K. in K Cl........	101 100	4.10 4.26	83	71
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl......	115 115	4.92 4.94	95	84

* Ann. Rpts. 7, 168–182 (1894); 8, 215–231 (1895); 9, 221–241 (1896); 10, 226–240 (1897); 11, 137–143 (1898); 16, 237–267 (1903); 19, 186–316 (1906); 20, 299–357 (1907); and Bulletins 104 and 106 (1905).

The results indicate that sodium is beneficial with millet, as with wheat, when it supplements an amount of potassium which is insufficient to produce maximum growth. With eight parts of potassium in potassium chlorid, per million of solution (8 ppm. K. in K Cl), the relative transpiration (evaporation from the leaves) and weight of the green seedlings were 83 and 71, respectively, as compared with 100 when the plants had received an abundance of potassium. The addition of fourteen parts of sodium in sodium chlorid, per million of solution (14 ppm. Na. in NaCl), increased the transpiration and green weight to 95 and 84.

The results secured with oats are recorded in table II.

TABLE II.

Effect of Sodium on Oat Seedlings.

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
Experiment I.				
32 ppm. K. in K Cl........	159 189	4.30 4.72	100	100
8 ppm. K. in K Cl........	155 154	3.60 3.51	89	79
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl......	186 188	4.31 4.26	108	94
Experiment II.				
32 ppm. K. in K Cl........	210 173	4.87 4.16	100	100
8 ppm. K. in K Cl........	160 173	3.40 3.63	87	78
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl......	172 179	4.04 4.02	92	89

This table shows that the growth of the oat seedlings was likewise increased by the addition of sodium to an amount of potassium which was insufficient for the maximum growth of the seedlings.

The results of two experiments with rye seedlings may be seen by reference to table III.

TABLE III.

Effect of Sodium on Rye Seedlings.

SPECIAL ADDITIONS.	FROM EACH BOTTLE.				RELATIVE.			
	Transpiration.		Green weight.		Transpiration.		Green weight.	
	Expt. I.	*Expt. II.*	*Expt. I.*	*Expt. II.*	*Expt. I.*	*Expt. II.*	*Expt. I.*	*Expt. II.*
32 ppm. K. in K Cl....	188 209	220 228	4.94 4.90	5.52 5.10	100	100	100	100
8 ppm. K. in K Cl....	164 152	183 192	3.78 3.90	3.88 3.91	80	84	78	73
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl..	165 177	189 220	3.66 3.99	4.21 4.23	87	91	78	79
4 ppm. K. in K Cl....	110 128	148 133	3.29 3.24	3.25 3.43	60	62	66	63
4 ppm. K. in K Cl, and 16 ppm. Na. in Na Cl..	119 141	154 166	3.40 3.53	3.58 3.64	66	71	71	68
2 ppm. K. in K Cl....	80 68	95 99	2.36 2.40	2.66 2.93	37	43	48	53
2 ppm. K. in K Cl, and 18 ppm. Na. in Na Cl..	73 74	100 101	2.84 2.80	3.03 2.82	37	45	57	55

By referring to the relative green weights in experiment I, in this table, it may be seen that a reduction in the amount of potassium from 32 to 8 ppm. resulted in a depression of over 20 per cent., as is usual with wheat seedlings, but when there was added an amount of sodium chlorid equivalent to the 24 ppm. of potassium which was

withheld, the relative green weight was not increased. In experiment II, however, there was an increase under these circumstances. There were a number of instances in the case of the rye seedlings, considering both the transpiration and green weight, in which the substitution of potassium by equivalent amounts of sodium resulted in scarcely any increase over that obtained with the reduced amount of potassium alone. The experiment recorded in table IV was therefore conducted with wheat and rye at the same time and under identical circumstances, to find out if any difference exists in the two cereals regarding the question under discussion.

Table IV.

Comparative Effect of Sodium on Wheat and Rye Seedlings.

Special Additions.	From Each Bottle.				Relative.			
	Transpiration.		Green weight.		Transpiration.		Green weight.	
	Wheat.	*Rye.*	*Wheat.*	*Rye.*	*Wheat.*	*Rye.*	*Wheat.*	*Rye.*
32 ppm. K. in K Cl........	212 194	252 243	5.60 5.31	4.93 5.26	100	100	100	100
8 ppm. K. in K Cl........	143 150	189 193	3.83 3.86	3.89 4.19	72	77	71	79
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl......	195 181	220 203	4.84 4.40	4.40 4.24	92	85	85	85
4 ppm. K. in K Cl........	112 105	136 135	3.01 2.90	3.38 3.51	53	55	54	68
4 ppm. K. in K Cl, and 16 ppm. Na. in Na Cl......	178 158	160 156	4.51 4.33	3.70 3.74	83	64	81	73
2 ppm. K. in K Cl.........	81 99	117 103	2.26 2.42	2.58 2.81	44	45	43	53
2 ppm. K. in K Cl, and 18 ppm. Na. in Na Cl......	139 141	103 126	3.66 3.64	2.76 2.90	69	46	67	55

It may be seen at once, by reference to the table, that the reductions in the amount of potassium affected the wheat much more seriously than the rye, especially when the relative green weights are considered. This indicates that the requirements for potassium were greater with wheat than with rye. In spite of this indication, however, the addition of sodium to the various amounts of potassium, which were insufficient for the needs of the plants, increased the relative green weights of the wheat so much more than those of the rye that the former more nearly approached the maximum which was obtained with the full amount of potassium. In other words, the wheat was benefited much more than the rye by the addition of sodium. The percentage increase in green weight from supplementing 8, 4, and 2 ppm. of potassium with sodium was 20, 50, and 56, respectively, with the wheat, and only 8, 7, and 4 with the rye.

The comparative effect of sodium on barley and rye seedlings was likewise tested; and the results of the two experiments are embodied in table V.

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Table V.

Comparative Effect of Sodium on Barley and Rye Seedlings.

Special Additions.	From Each Bottle.				Relative.			
	Transpiration.		Green weight.		Transpiration.		Green weight.	
Experiment I.	*Barley.*	*Rye.*	*Barley.*	*Rye.*	*Barley.*	*Rye.*	*Barley.*	*Rye.*
32 ppm. K. in K Cl	111 125	131 136	4.69 5.23	4.33 4.46	100	100	100	100
8 ppm. K. in K Cl.........	107 106	120 127	3.75 3.70	3.24 3.12	91	93	75	72
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl.......	115 113	126 118	4.20 4.15	3.21 3.33	97	92	84	74
Experiment II.								
32 ppm. K. in K Cl.........	135 147	155 148	5.00 5.52	4.76 4.90	100	100	100	100
8 ppm. K. in K Cl.........	114 117	124 136	3.25 3.38	3.21 3.33	82	86	63	68
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl......	130 135	130 132	4.31 4.22	3.40 3.35	94	86	81	70

The relative depression, in both transpiration and green weight, caused by reducing the amount of potassium from 32 to 8 ppm. is, on the whole, not very different with the two cereals; but, as was the case with wheat, the barley responded to the added sodium to a much greater extent than the rye. In the case of the rye, in both experiments, the relative transpiration was not increased by the sodium, and the green weight only 3 per cent.; whereas with the barley the green weight was increased 12 and 29 per cent., respectively, in experiments I and II.

It is evident that rye seedlings, as compared with the other seedlings which have been tested, profit very little from the addition of sodium, even when the potassium is very deficient.

Marked differences in the comparative effect of sodium on different crops have been noticed in the field. It must be borne in mind, however, that in the field the indirect effect of sodium cannot be eliminated.

At the Bernburg Station in Germany a number of experiments* which yielded much information bearing on the sodium question were carried out by Hellriegel, Wilfarth, and their co-workers, in quartz sand, or sand and peat, which had been treated with acid in order to remove practically all of the available potassium. The plants were grown to maturity. A few of the results are condensed in table VI, and serve to show that year after year, with barley and oats, an increase in the crop resulted when a deficient amount of potassium was supplemented by sodium. It is probable that certain other crops, as the results with buckwheat and potatoes indicate, may not be benefited by sodium.

In table VI the results with one crop should not be compared with those secured with another, for the experiments were not always carried on under the same conditions. The plants were supplied liberally with nitrogen and phosphorus, and the crop which is recorded as having been produced with the liberal amount of potassium probably approached the maximum. A comparison of these amounts with those in the next column gives an idea of the extent of the deficiency of potassium. This is important when considering the effect of an addition of sodium to the deficient amount of potassium.

Except for the evidence afforded by the experiments in solution which have been carried on at the Rhode Island Station, one would hesitate to draw the conclusion, from the results with sand and peat, that the benefits resulting from the sodium were due to a direct action, for it might be assumed fairly that the sodium prevented some slight fixation of potassium by the medium in which the plants were grown, so that slightly more was available when the sodium was present. Under conditions where the lack of potassium was so great it would be expected that a small increase in its avail-

* Arb. Deut. Landw. Gesell, Hefts 34 and 38.

ability would materially influence the crop. As a matter of fact the total amount of potassium removed by the plants was increased almost without exception when the small application of potassium was accompanied by sodium; and frequently the percentage increase in yield was not greater than that in the amount of potassium removed.

Table VI.

Effect of Sodium on Different Crops Grown in Sand at the Bernburg Experiment Station in Germany.

(Air-dry, mature, above-ground crop, per pots, grams.)

Kind of Crop.	Year.	Liberal amount potassium.	Deficient amount potassium.	Deficient amount potassium plus sodium.
Barley	1892	26.461	9.370	16.505
	1893	21.247	9.024	11.970
	1894	33.784	13.954	21.423
Oats	1892	16.545	9.739	15.414
	1893	21.992	10.219	11.861
	1894	27.194	14.958	21.105
	1895	31.324	14.906	22.606
Peas	1893	22.377	10.042	15.589
	1894	35.966	23.767	25.813
Lupin	1894	37.423	27.015	32.217
Buckwheat	1900	27.799	13.280	10.692
Potatoes (tubers)	1899	125.19	70.40	66.85
	1900	144.40	52.00	47.49

In obtaining the results thus far presented concerning the effect of sodium in solution, we have substituted it for approximately equivalent amounts of potassium; and the growth has been com-

pared especially with that where the small amount of potassium was not accompanied by sodium. The results of the two experiments with barley and wheat, which are contained in table VII, show the effect of increasing the sodium beyond the amount equivalent to the potassium which it substituted.

TABLE VII.

The Effect on Barley Seedlings of Increasing the Amount of Sodium.

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
32 ppm. K. in K Cl........	98 107	4.86 5.28	100	100
4 ppm. K. in K Cl........	73 75	2.89 3.00	72	58
4 ppm. K. in K Cl, and 16 ppm. Na. in Na Cl......	113 109	4.63 4.31	108	88
4 ppm. K. in K Cl, and 32 ppm. Na. in Na Cl......	106 101	4.67 4.50	100	91
4 ppm. K. in K Cl, and 48 ppm. Na. in Na Cl......	106 106	4.51 4.78	103	92

It may be seen that doubling and tripling the amount of sodium which was equivalent to the replaced potassium did not increase the growth of the barley seedlings to any marked extent.

A similar experiment with wheat seedlings is recorded in table VIII. In connection with 8 ppm. of potassium the maximum amount of sodium appeared to increase the relative green weight somewhat more than the smaller amounts, but this was due to an increase in the weight from only one of the bottles.

TABLE VIII.

The Effect on Wheat Seedlings of Increasing the Amount of Sodium.

Special Additions.	From Each Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
32 ppm. K. in K Cl........	98 102	4.53 4.47	100	100
8 ppm. K. in K Cl........	71 69	3.02 2.98	70	67
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl......	100 95	4.02 4.15	98	91
8 ppm. K. in K Cl, and 28 ppm. Na. in Na Cl......	97 96	3.80 4.25	96	90
8 ppm. K. in K Cl, and 42 ppm. Na. in Na Cl......	98 99	4.18 4.50	99	96
4 ppm. K. in K Cl........	71 67	2.72 2.60	69	59
4 ppm. K. in K Cl, and 16 ppm. Na. in Na Cl......	86 83	3.59 3.55	85	82
4 ppm. K. in K Cl, and 32 ppm. Na. in Na Cl......	92 83	3.81 3.64	87	82
4 ppm. K. in K Cl, and 48 ppm. Na. in Na Cl......	89 90	3.99 3.84	89	87

When the sodium was added with only 4 ppm. of potassium, the table shows that there was a slight increase in growth with each increase in the application. This was scarcely noticeable in connection with the preceding experiment with the barley.

The minimum amount of potassium, 4 ppm., when present without sodium, in certain series of the two preceding experiments, resulted in very abnormal plants. The roots were long, but were branched

comparatively little; and the leaves were frequently tipped with brown, and showed evidences of malnutrition. There was unquestionably a somewhat reduced percentage of water in these plants, so that the green weights are not strictly comparable; but it is interesting, nevertheless, to notice the very considerable beneficial effect exerted by sodium under the exaggerated conditions which were brought about in these experiments. It should be stated that in the main portion of the work which has been reported previously on the study of the effect of sodium, the potassium had not been withheld to such an extent as to cause serious injury to the plants aside from retarding their growth. In the present experiment the addition of sodium to 4 ppm. of potassium resulted in the production of plants which were normal in appearance, having well-branched roots, and leaves of normal color. In fact the growth was much more normal with 4 ppm. of potassium plus sodium than with twice this amount of potassium without sodium. In a number of similar experiments, recorded previously, the tendency was usually in the same direction.

A comparative study of a large number of analyses* of the ashes of plants, grown at this Station in connection with the field experiment on the effect of sodium salts, brought out the fact that the percentage of phosphoric acid was usually increased when the application of sodium in connection with a small amount of potassium was raised from a one-fourth to a full ration. The result was more marked in the case of the carbonate than of the chlorid of sodium. The increase in the application of sodium resulted in the majority of cases in a larger crop, and on this account the question was considered as to whether the beneficial effect of sodium was in some way related to the absorption or metabolism of phosphorus. The attempt was made to have the field applications of the phosphate so large that there would be no deficiency in any plat; and it seemed unreasonable to suppose that, especially with a small amount of potassium, there was any need by the plants for the increased percentage of phosphoric

*Ann. Rpt. 19, 186–316 (1906).

acid which accompanied the increased applications of sodium. Furthermore, when the amount of potassium was sufficient, maximum crops were produced in many cases when the percentage of phosphoric acid was less than resulted from an increase in the application of sodium. It was thought probable, therefore, that the extra absorption of phosphorus "was an incidental accompaniment of the employment of sodium salts rather than the cause of the increased growth which resulted." The sodium salts had apparently increased the amount of available phosphorus, and the plants had simply absorbed it somewhat relatively to the amount present.

In the solution experiments all of the phosphorus was in a soluble form, and any effect which sodium might exert upon the phosphorus would be in connection either with the absorption or metabolism of the latter. A few determinations of the amount of phosphorus pentoxid (phosphoric acid) in the seedlings were made for the purpose primarily of obtaining evidence of any connection which may have existed between the presence of sodium and the removal of phosphorus by the seedlings. The results are condensed in table IX.

The first two series of experiment I show that in connection with an optimum amount of potassium, 32 ppm., the average percentage of phosphorus pentoxid in the plant was 1.19 when 4 ppm. of phosphorus (P) were contained in the solution, and 2.37 when the amount of phosphorus was increased to 15 ppm. of solution, which was the usual amount employed previously. The percentage of phosphorus pentoxid in the plant was doubled, not only without any advantage, but, in this particular case, with a slight disadvantage. A still greater depression of green weight resulted in connection with an increase in the amount of phosphorus in the third series as compared with the fourth.

TABLE IX.

Effect of Varying Amounts of Nutrients on the Amount of Phosphorus Pentoxid Absorbed by Wheat Seedlings.

SPECIAL ADDITIONS.	WEIGHT FROM EACH BOTTLE, GRAMS.				
	Green tops.	Dry tops.	Dry roots.	Phosphorus pentoxid in tops and roots.	Per cent. of phosphorus pentoxid in dry tops and roots.
Experiment I.					
15 ppm. P, 32 ppm. K....	6.86	.833	.437	.0274	2.16
	6.59	.716	.352	.0274	2.57
4 ppm. P, 32 ppm. K....	7.05	.841	.486	.0152	1.15
	7.50	.903	.477	.0168	1.22
15 ppm. P, 4 ppm. K, and 16 ppm. Na.............	4.21	.475	.236	.0209	2.94
	4.63	.526	.265	.0234	2.96
4 ppm. P, 4 ppm. K, and 16 ppm. Na.............	6.28	.917	.421	.0191	1.43
Experiment II.					
15 ppm. P, 8 ppm. K.....	3.92	.572	.307	.0176	2.00
15 ppm. P, 8 ppm. K, and 14 ppm. Na.............	4.65	.630	.353	.0217	2.21
8 ppm. P, 8 ppm. K.....	3.70	.531	.273	.0166	2.06
8 ppm. P, 8 ppm. K, and 14 ppm. Na.............	4.77	.678	.316	.0185	1.88
	4.60	.650	.328	.0182	1.86
Experiment III.					
15 ppm. P, 4 ppm. K.....	3.01	.368	.201	.0166	2.93
	2.96	.367	.203	.0159	2.77
15 ppm. P, 4 ppm. K, and 16 ppm. Na.............	3.42	.407	.242	.0153	2.36
	3.78	.435	.253	.0179	2.60
4 ppm. P, 4 ppm. K.....	3.24	.404	.202	.0108	1.78
	3.11	.381	.219	.0112	1.87
4 ppm. P, 4 ppm. K, and 16 ppm. Na.............	3.68	.427	.255	.0115	1.69
	3.72	.445	.235	.0112	1.65

The effect, upon the absorption of phosphorus, of the addition of sodium to deficient amounts of potassium may be observed in experiments II and III, likewise recorded in table IX. In experiment II more phosphorus pentoxid was removed by the seedlings when the sodium was present; the results, however, were usually not obtained in duplicate. In experiment III, however, when no such increase was shown, duplicate tests were made. Owing to the increased growth which results from adding sodium to a deficient amount of potassium, the percentage of phosphorus pentoxid was usually decreased, even when the total amount remained unchanged. It seemed likely that no light on the reason for the beneficial effect of sodium was to result from a further pursuance of this course; and that the increased absorption of phosphorus which accompanied additions of sodium in the field simply resulted from an unrequired increase in the amount of phosphorus which was rendered available, rather than to any direct effect of sodium on the ability of the plant to absorb phosphorus. The table contains numerous instances like those in the field in which a smaller yield accompanied a larger percentage of phosphorus pentoxid. The belief that the increase in the percentage of phosphorus pentoxid in the plant, which frequently accompanied extra applications of sodium in the field, was not the cause of the increase in crop is strengthened by these results.

A number of instances are exhibited in the table in which changes in the nutrient solution, involving only the reduction of its content of phosphorus, have resulted in a slight increase in yield as well as in a reduction in the percentage of phosphorus pentoxid. Inasmuch as the addition of sodium likewise usually decreased the percentage, it might be argued that sodium was useful in part in preventing too great a percentage accumulation of phosphorus in seedlings grown in a nutrient solution containing an excess of this element. That 15 ppm. of phosphorus is an abundance was shown in the last annual report by the failure of larger amounts to increase the growth. On the contrary the growth was slightly depressed in some instances, especially when deficient amounts of potassium were unaccompanied

by sodium. It became necessary, therefore, to ascertain if reductions in the amounts of phosphorus would have any effect upon the degree of benefit resulting from sodium. A number of tables follow which contain the results of this line of work. Certain comparisons will be briefly made following each table, but the general discussion will be postponed until all the tabulated results have been presented.

It may be seen in table X that the reduction of nitrogen (N) to 21 ppm. from the usual amount, 42 ppm., resulted in a depression of growth, except when the alkalies were limited to only 8 ppm. of potassium alone. No evidence was obtained, therefore, that a reduction in the amount of nitrogen would have been desirable.

The reduction in the amount of phosphorus from 15 ppm. to 8 ppm. depressed the growth slightly in connection with the full amount of potassium; but 8 ppm. of phosphorus seemed to be sufficient with 8 ppm. of potassium alone or accompanied by sodium.

TABLE X.

The Influence of a Reduction in the Amounts of Phosphorus and Nitrogen upon the Effect of Sodium on Wheat Seedlings.

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
32 ppm. K. in K Cl.				
15 ppm. P, and 42 ppm. N.	246 244	6.37 6.36	100	100
15 ppm. P, and 21 ppm. N.	219 203	5.40 4.78	86	80
8 ppm. P, and 42 ppm. N.	240 228	6.26 5.98	97	96
8 ppm. K. in K Cl.				
15 ppm. P, and 42 ppm. N.	166 165	3.68 3.92	68	60
15 ppm. P, and 21 ppm. N.	172 172	3.93 3.68	70	60
8 ppm. P, and 42 ppm. N.	165 151	4.11 3.70	64	61
8 ppm. K. in K Cl, and 14 ppm. Na. in Na_2SO_4				
15 ppm. P, and 42 ppm. N.	202 196	4.65 4.58	81	72
15 ppm. P, and 21 ppm. N.	186 190	4.02 4.26	77	65
8 ppm. P, and 42 ppm. N.	197 185	4.77 4.60	78	74

TABLE XI.

The Influence of a Reduction in the Amount of Phosphorus upon the Effect of Sodium on Wheat Seedlings.

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
32 ppm. K. in K Cl.				
15 ppm. P.	186 188	5.53 5.63	100	100
4 ppm. K. in K Cl.				
15 ppm. P.	92 99	3.01 2.96	51	54
4 ppm. P.	104 109	3.24 3.11	57	57
2 ppm. P.	113 113	3.40 3.34	60	60
4 ppm. K. in K Cl, and 16 ppm. Na. in Na_2SO_4				
15 ppm. P.	118 126	3.42 3.78	65	65
4 ppm. P.	126 136	3.68 3.72	70	66
2 ppm. P.	134 135	3.60 3.92	72	67

In table XI it may be seen that, with 4 ppm. of potassium alone, better results were obtained when the phosphorus was reduced even to only 2 ppm. The relative transpiration was increased from 51 to 60 and the relative green weight from 54 to 60. Likewise when 4 ppm. of potassium were supplemented by sodium in sodium sulfate (Na_2SO_4) there was an increase accompanying the reduction of phosphorus, although it was less in amount. The growth of the

plant was depressed so seriously by limiting it to 4 ppm. of potassium that even 2 ppm. of phosphorus was sufficient. The increase in green weight due to the addition of sodium to 4 ppm. of potassium was 20 per cent. with 15 ppm. of phosphorus, 16 per cent with 4 ppm., and 12 per cent. with 2 ppm., a uniform decrease in the effect of sodium with decreasing amounts of phosphorus.

TABLE XII.

The Influence of a Reduction in the Amount of Phosphorus upon the Effect of Sodium on Wheat Seedlings.

Special Additions.	From Each Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
64 ppm. K. in K Cl.				
32 ppm. P................	170 161	7.93 7.39	100	100
8 ppm. P...............	153 164	7.95 7.52	96	101
2 ppm. P................	166 152	6.79 6.52	96	87
8 ppm. K. in K Cl.				
32 ppm. P................	118 123	4.11 3.93	73	52
8 ppm. P................	122 131	4.57 4.60	76	60
2 ppm. P................	123 119	4.11 4.12	73	54
8 ppm. K. in K Cl, and 39 ppm. Na. in NaCl.				
32 ppm. P................	148 131	5.30 5.04	84	67
8 ppm. P................	151 145	5.58 5.19	90	70
2 ppm. P................	151 140	4.85 4.46	86	61

In order to secure a still greater range in the amount of phosphorus about twice the usual amount of solids was used in the experiment which is recorded in table XII, resulting in 64 ppm. of potassium and 32 ppm. of phosphorus as the maximum amounts in solution. With even the largest amount of potassium, 8 ppm. of phosphorus seemed to be enough, whereas a reduction to 2 ppm. depressed the green weight 13 per cent. In connection with 8 ppm. of potassium without sodium, 8 ppm. of phosphorus gave the largest growth, and only 2 ppm. produced as much as 32 ppm. When the sodium was present, however, the green weight indicated that 2 ppm. of phosphorus were insufficient. The gain from the addition of sodium again decreased with the decreasing amount of phosphorus, amounting in this experiment to 29, 17, and 11 per cent., respectively.

The results which are given in the next table, XIII, afford a strict comparison of the growth with the chlorids of potassium and sodium and that with the carbonates. The plants were grown at the same time, and under the same conditions. The relative transpiration and green weight are each based upon 100, which represents the data secured with 32 ppm. of potassium in chlorid and 15 ppm. of phosphorus.

With 32 ppm. of potassium and 15 ppm. of phosphorus, the carbonate produced less than the chlorid, but this was not the case when only 4 ppm. of phosphorus were present. With 8 ppm. of potassium, the chlorids produced a better growth than the carbonates in the case of both 15 ppm. and 4 ppm. of phosphorus. When the sodium was present, however, the growth with the chlorids and carbonates was about alike with 15 ppm. of phosphorus; but with 4 ppm. of phosphorus the growth was considerably better in the case of the carbonate.

TABLE XIII.

The Influence of a Reduction in the Amount of Phosphorus upon the Effect of Sodium on Wheat Seedlings.

Special Additions.	From Each Bottle.				Relative.			
	Transpiration.		Green weight.		Transpiration.		Green weight.	
	Chlorid.	Carbonate.	Chlorid.	Carbonate.	Chlorid.	Carbonate.	Chlorid.	Carbonate.
32 ppm. K.								
15 ppm. P..........	309 300	292 279	7.10 7.10	6.42 6.43	.100	94	100	91
4 ppm. P..........	310 310	305 326	6.82 6.92	6.80 7.26	102	104	97	99
8 ppm. K.								
15 ppm. P..........	227 208	185 190	4.75 4.55	3.97 4.28	71	62	66	58
8 ppm. P..........	195 198	....	4.72 4.76	......	64	......	67	......
4 ppm. P..........	214 212	201 210	5.14 5.18	4.95 4.42	70	67	73	66
2 ppm. P..........	229 220	....	5.20 4.78	......	74	......	70	......
8 ppm. K, and 14 ppm. Na.								
15 ppm. P..........	246 237	252 242	5.54 5.07	5.26 5.22	79	81	75	74
8 ppm. P..........	226 255	....	5.49 5.60	....	79	......	78	......
4 ppm. P..........	249 240	271 279	5.50 5.72	5.87 6.12	80	90	79	84
2 ppm. P..........	265 258	....	5.09 4.98	....	86	......	71	......

A reduction in the amount of phosphorus from 15 to 4 ppm. seemed to be especially advantageous with the carbonates; and, in order to ascertain if this observation would be repeated, two more similar experiments were conducted, the results of which are presented in table XIV.

TABLE XIV.

The Influence of a Reduction in the Amount of Phosphorus upon the Effect of Sodium on Wheat Seedlings.

SPECIAL ADDITIONS.	FROM EACH BOTTLE.				RELATIVE.			
	Transpiration.		Green weight.		Transpiration.		Green weight.	
	Expt. I.	*Expt. II.*	*Expt. I.*	*Expt. II.*	*Expt. I.*	*Expt. II.*	*Expt. I.*	*Expt. II.*
15 *ppm. P.*								
32 ppm. K. in K_2CO_3.......	208 188	137 153	5.02 4.70	4.72 4.83	100	100	100	100
8 ppm. K. in K_2CO_3.......	174 172	100 106	4.24 3.72	3.13 3.48	87	70	82	69
8 ppm. K. in K_2CO_3, and 14 ppm. Na. in Na_2CO_3.....	201 181	116 119	4.66 4.28	3.92 3.78	96	80	92	81
4 *ppm. P.*								
32 ppm. K. in K_2CO_3.......	188 182	150 153	4.25 4.32	4.21 4.69	93	104	88	94
8 ppm. K. in K_2CO_3.......	148 138	114 120	3.83 3.54	3.57 3.41	72	81	72	73
8 ppm. K. in K_2CO_3, and 14 ppm. Na. in Na_2CO_3.....	181 168	125 126	4.03 3.96	3.91 3.94	88	87	82	82

With the amounts of potassium carbonate (K_2CO_3) and sodium carbonate (Na_2CO_3) stated in this table, there seems to be no especial advantage, on the whole, in reducing the amount of phosphorus to 4 ppm. Perhaps such would not have been the case had the amount of potassium also been reduced to 4 ppm., as in a number of pre-

ceding instances. It should be recalled, however, that 4 ppm. of potassium is insufficient to keep the seedlings in a healthy condition when other circumstances would tend to promote rapid growth; and the tips of the leaves frequently turn brown.

The work thus far recorded concerning the beneficial action of sodium has been conducted with mono-calcium phosphate as the source of phosphorus, and a small amount of ferric nitrate to furnish the iron. A few results are now given in table XV, which also includes some secured with ferric, and tri-calcium phosphates.

The ferric and tri-calcium phosphates were the dry so-called c. p. salts, and an excess of each was added in suspension. The combined ferric and tri-calcium phosphates appeared to furnish practically enough phosphorus when only 4 ppm. of potassium were present. There was a beneficial effect of sodium regardless of the form and amount of phosphorus, as may be noted also in tables XVI and XVII, which show that the ferric phosphate, when used alone, did not furnish sufficient available phosphorus for any of the series. The sodium again appeared to be beneficial regardless of whether phosphorus and iron were furnished in easily soluble salts or by comparatively insoluble compounds in suspension.

In the experiments which demonstrated that sodium was beneficial to certain seedlings when the amount of potassium was somewhat deficient, it was always necessary to be assured that a deficiency of potassium existed. This was done by comprising one series in the experiments, in which all of the nutrients, including potassium, were present in optimum amounts. It was determined experimentally that about 32 ppm. of potassium were usually sufficient to produce maximum growth under the conditions of the experiments. To the series which were expected to be markedly deficient in potassium only a fourth or an eighth of this amount was usually added. It was recognized at the outset that the very considerable depression in the growth of the seedlings, usually amounting to from 30 to 40 per cent., which accompanied the reduction of potassium might not be entirely due to the lack of this element, but possibly in part to a disturbance

TABLE XV.

The Influence of Phosphorus, in Different Amounts and Compounds, upon the Effect of Sodium on Wheat Seedlings.

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
Ferric and tri-calcium phosphates.				
32 ppm. K. in K Cl........	130 144	4.76 5.47	100	100
4 ppm. K. in K Cl........	89 70	2.91 2.63	58	54
4 ppm. K. in K Cl, and 16 ppm. Na. in Na Cl......	119 103	4.08 3.60	81	75
15 *ppm. P. in mono-calcium phosphate.*				
4 ppm. K. in K Cl........	90 87	2.84 2.63	64	54
4 ppm. K. in K Cl, and 32 ppm. Na. in Na Cl......	131 134	4.28 4.42	96	85
4 ppm. K. in K Cl, and 48 ppm. Na. in Na Cl......	131 124	4.38 4.36	93	85
30 *ppm. P. in mono-calcium phosphate.*				
4 ppm. K. in K Cl........	93 78	2.61 2.60	62	51
4 ppm. K. in K Cl, and 16 ppm. Na. in Na Cl......	109 121	3.71 4.05	84	76

in the balance of the nutrient solution due to the reduction in the amount of potassium without a corresponding lessening of the other nutrients. If such were the case, the beneficial effects of sodium when accompanying deficient amounts of potassium might be due

to overcoming a detrimental action of some constituent of the solution; or, in other words, to an improvement in the balance of the solution.

Table XVI.

The Influence of Phosphorus, in Different Amounts and Compounds, upon the Effect of Sodium on Wheat Seedlings.

Special Additions.	From Each Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
Ferric phosphate.				
32 ppm. K. in K Cl........	141 134	4.11 3.98	100	100
4 ppm. K. in K Cl........	113 102	3.23 3.11	78	78
4 ppm. K. in K Cl, and 16 ppm. Na. in Na Cl......	119 121	3.53 3.63	88	88
Ferric and tri-calcium phosphate.				
32 ppm. K. in K Cl..	158 159	4.79 4.56	116	116
4 ppm. K. in K Cl........	89 98	3.17 3.49	68	82
4 ppm. K. in K Cl, and 16 ppm. Na. in Na Cl......	137 122	4.16 3.66	94	97
Mono-calcium phosphate.				
32 ppm. K. in K Cl........	148 148	4.76 4.85	108	116
4 ppm. K. in K Cl........	112 103	3.66 3.51	78	89
4 ppm. K. in K Cl, and 16 ppm. Na. in Na Cl......	113 117	3.45 3.88	84	91

TABLE XVII.

The Influence of Phosphorus, in Different Amounts and Compounds, upon the Effect of Sodium on Wheat Seedlings.

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
Ferric phosphate.				
32 ppm. K. in K Cl........	101 95	4.38 4.43	100	100
8 ppm. K. in K Cl........	86 89	3.40 3.74	90	81
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl......	78 87	3.78 3.63	84	85
Ferric and tri-calcium phosphate.				
32 ppm. K. in K Cl........	94 96	4.68 4.46	97	104
8 ppm. K. in K Cl........	77 77	4.17 4.11	79	94
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl......	99 97	4.55 4.21	100	99

These considerations led to the avoidance, in so far as practicable, of the use of a solution containing much excess of the principal nutrients over what was required for the production of normal growth, and to a quite thorough study of the effect of sodium with many modifications of the nutrient solution.

It was shown in the last annual report that an increase in the amount of phosphorus from 15 to 30 ppm., when the potassium was somewhat deficient, was inclined to slightly depress the growth; and some of the experiments which have immediately preceded have indicated a slight possible increase in growth when the small amount

of potassium, without sodium, was accompanied by a reduction in the amount of phosphorus in mono-calcium phosphate to less than 15 ppm. In fact, under these conditions, very little phosphorus seems to be required for the somewhat limited production. It has been reduced to as little as 2 ppm. without causing a depression of growth, but it has been seen that sufficient phosphorus was not secured when ferric phosphate was the source.

When sodium was present with the deficient amount of potassium, however, it would scarcely have been said that a reduction in the amount of phosphorus resulted in any increase in green weight; and when the extreme reduction in phosphorus was made there was, instead, a depression of growth, so that not infrequently the green weight was no greater when sodium was present than when absent.

This apparent tendency, shown in some of the early experiments, for a slight increase in growth to accompany a reduction in the amount of mono-calcium phosphate, when added with a deficient amount of potassium without sodium, indicated that possibly even small amounts of mono-calcium phosphate were somewhat toxic when unaccompanied by the optimum amount of potassium. When it was noted that sodium frequently failed to cause any increase in growth, provided the amount of mono-calcium phosphate was reduced sufficiently low, it seemed possible that some of the beneficial effects of sodium which had been noted might be due to its counteracting a possible toxicity exerted by mono-calcium phosphate when only small amounts of potassium were present. This explains why so many experiments have been conducted with varying amounts and kinds of phosphates. As a result of these experiments it appears that no constant increase in growth does accompany the reduction of phosphorus within the narrow limits to which most of the experiments were confined; and that the apparent increases, which made further work seem necessary, were usually too small to be considered as outside of the limit of error. The failure of sodium to act beneficially when the phosphorus was reduced to very low limits was without doubt because the amount of phosphorus was so small that

its lack became the factor preventing the further growth which sodium was able to cause when sufficient amounts of phosphorus were present.

It had been noticed sometimes that a reduction in the amount of potassium caused a somewhat chlorotic condition of the seedlings, and that the extent of this appearance was influenced frequently by certain of the nutrients associated with the deficient potassium. An amount of phosphorus, for example, which was considerably greater than that required to balance the small amount of potassium, at times increased the chlorosis. On the other hand, the addition of sodium to deficient amounts of potassium was apt to result in a better color.

In order to exaggerate those conditions which had frequently been accompanied by chlorosis, and to ascertain if doubling the amount of iron (Fe) would improve the plants, the experiment outlined in table XVIII was conducted.

This table shows that in connection with 32 ppm. of potassium it seemed to be immaterial whether 45 or 15 ppm. of phosphorus were used; a depression to 4 ppm., however, resulted in a reduction of green weight, although this was not so when only 16 ppm. of potassium were present.

With only 8 ppm. of potassium, the plants showed signs of malnutrition. The amount of phosphorus was so large that conditions favorable to chlorosis existed, according to our experience. The leaves were in fact of a much lighter green color, but were not so chlorotic as had been observed at other times. In no case was any advantage derived from an increase in the amount of iron.

The greatest tendency towards chlorosis had been when the deficient amount of potassium was in carbonate; accordingly the effects of different amounts of iron with this salt are next shown, in table XIX.

The amount of iron which has been used in most of the experiments was equal to 2.7 parts hydrous ferric nitrate per million of solution, and it may be seen by table XVIII that no advantage was

TABLE XVIII.

The Growth of Wheat Seedlings under Certain Conditions Tending to Promote Chlorosis.

Special Additions.	From Each Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
32 ppm. K. in K Cl.				
15 ppm. P	226 212	6.18 5.57	100	100
15 ppm. P, and 5 cc. $\frac{N}{10}$ Na OH.	242 239	5.95 6.07	110	102
15 ppm. P, and 5 cc. $\frac{N}{10}$ Na OH, and extra Fe	235 224	5.92 5.71	104	98
45 ppm. P	215 223	5.66 5.66	100	97
4 ppm. P	212 211	4.88 4.98	97	83
4 ppm. P, one-eighth N	101 109	2.66 3.15	48	49
4 ppm. P, one-eighth N, and extra Fe	108 105	2.73 2.90	49	47
16 ppm. K. in K Cl.				
45 ppm. P	186 166	5.07 4.65	80	83
4 ppm. P	198 185	4.89 4.94	88	84
4 ppm. P, and extra Fe	185 181	5.07 4.80	84	84
8 ppm. K. in K Cl.				
45 ppm. P	169 153	4.49 3.86	74	71
45 ppm. P, and extra Fe	185 153	4.44 3.94	77	71

TABLE XIX.

The Effect of Different Amounts of Iron on the Growth and Color of Wheat Seedlings.

Special Additions.	From Each Bottle.		Relative.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
Experiment I.				
8 ppm. K. in K_2CO_3				
1.5 ppm. ferric nitrate, hydrous	159 167	3.20 3.30	100	100
2.2 ppm. ferric nitrate, hydrous	199 184	4.00 3.70	117	118
4.5 ppm. ferric nitrate, hydrous	196 199	3.80 3.97	121	120
Experiment II.				
8 ppm. K. in K_2CO_3				
0.7 ppm. ferric nitrate, hydrous	121 110	3.57 3.84	100	100
2.7 ppm. ferric nitrate, hydrous	109 112	3.30 3.80	96	96
5.4 ppm. ferric nitrate, hydrous	123 103	3.86 3.46	97	99

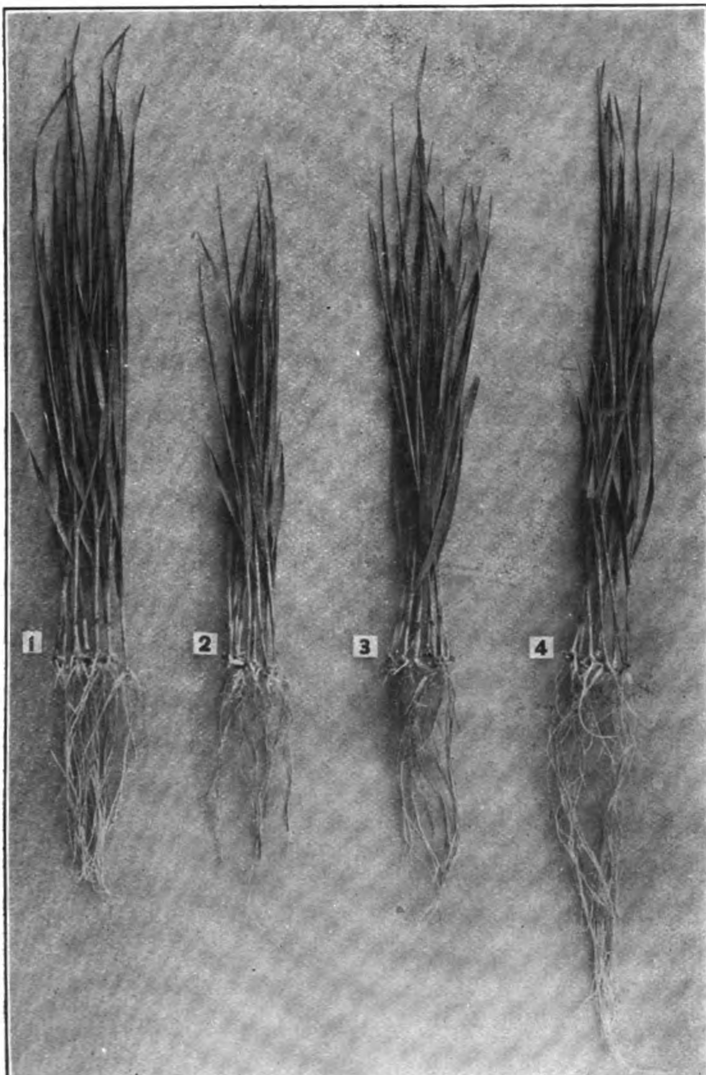
secured by a larger amount. In experiment I, of table XIX, however, a reduction to 1.5 ppm. resulted in a depression of both transpiration and green weight. Other observations also have led us to think that in the experiments with potassium and sodium carbonates it would have been undesirable at times to have used less iron than was ordinarily employed. In the two experiments under consideration the chlorosis was not so marked as had been noticed at other times with only 8 ppm. of potassium; and it is possible that under some conditions a larger amount of iron than had been used ordi-

narily would have decreased the chlorosis somewhat with carbonates, although it appears now as if it must have been due primarily to the unfavorable amounts of other nutrients than iron.

The nutrient solution which has been ordinarily used in our study of the effect of sodium contained 70 ppm. of calcium in calcium nitrate and mono-calcium phosphate, and 19 ppm. of magnesium in magnesium sulfate, making the proportion of calcium to magnesium as 3.7 to 1. Certain authorities have claimed that the ratio of about 1 to 1 is the most favorable, as a rule, for cereals, and the effect of adding a larger proportion of magnesium was therefore studied early in the work, the results having been recorded in the last annual report. The amount of magnesium was increased in some instances, so that it was slightly greater than that of calcium, without exerting any uniform improvement in the growth. Furthermore, comparative tests were made between the nutrient solution which has been used in most of the work and a quite different one, in which the calcium and magnesium were equal in amount, without noting any particular difference. It appears as if quite a considerable excess of calcium over magnesium results in no detriment in experiments conducted as here described.

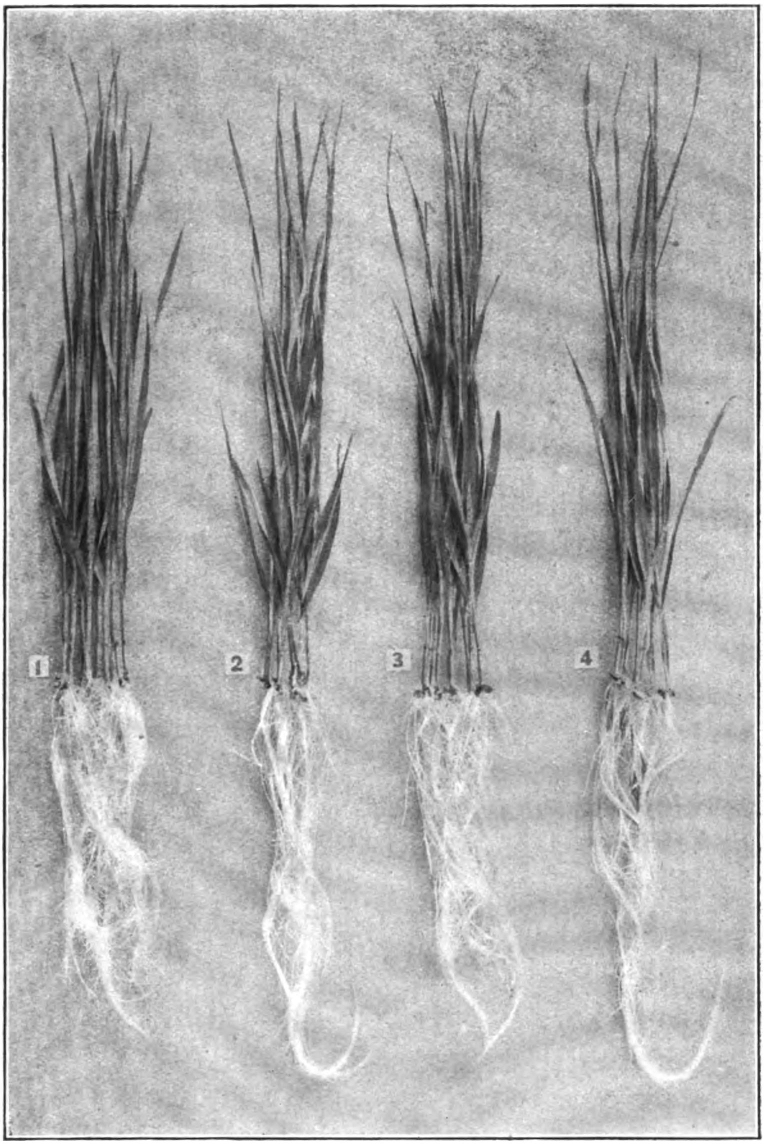
In table XX the result of replacing the calcium nitrate, $Ca(NO_3)_2$, by magnesium nitrate, $Mg(NO)_2$, may be seen. This substitution resulted in a much greater excess of magnesium over calcium than we had heretofore brought about, and it was desired to ascertain the effect of sodium under such conditions.

Some very interesting comparisons of the effects with the two nitrates may be made from the results which appear in the table. In a general way the relative transpiration and the dry weight of roots are usually quite similar, whereas the relative weight of tops exhibits some very decided differences from the two other criteria of growth. In comparing the effect on transpiration with that on green weight, it may be seen that according to transpiration the maximum growth was 43 per cent. greater with calcium nitrate than with magnesium nitrate, whereas the dry weight of tops was



Full Potassium.	Quarter Potassium.	Quarter Potassium, plus Sodium.	Quarter Potassium, plus Calcium.

FIG. 1.—MAGESIUM-NITRATE SERIES, page 273.



Full Potassium. | Quarter Potassium. | Quarter Potassium, plus Sodium. | Quarter Potassium, plus Calcium.

FIG. 2.—CALCIUM-NITRATE SERIES, page 273.

even slightly less. The same tendency is exhibited in all of the series; the transpiration being relatively much greater with the calcium nitrate, while as a rule there was not much difference in the weight of tops.

TABLE XX. (See figures 1 and 2.)

The Effect of Sodium on Wheat Seedlings when used with Various Ratios of Calcium to Magnesium.

Special Additions.	From Each Bottle.			Relative.		
	Transpiration.	Dry weight of tops.	Dry weight of roots.	Transpiration.	Dry weight of tops.	Dry weight of roots.
42 ppm. N. in $Mg(NO_3)_2$						
32 ppm. K. in K Cl..........	159 164	.750 .853	.256 .303	100	100	100
8 ppm. K. in K Cl.........	94 80	.576 .602	.173 .175	54	73	62
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl.......	148 150	.800 .753	.186 .200	92	97	69
8 ppm. K. in K Cl, and 12 ppm. Ca. in Ca Cl_2.......	144 140	.593 .564	.260 .255	88	72	92
42 ppm. N. in $Ca(NO_3)_2$						
32 ppm. K. in K Cl.........	231 230	.740 .745	.460 .424	143	93	158
8 ppm. K. in K Cl.........	144 150	.556 .580	.280 .295	91	71	103
8 ppm. K. in K Cl, and 14 ppm Na. in Na Cl.......	223 212	.699 .640	.400 .350	135	84	134
8 ppm. K. in K Cl, and 12 ppm. Ca. in Ca Cl_2.......	162 156	.599 .578	.285 .315	95	73	107

It was proven, as shown in the last annual report, that an additional amount of calcium could not at all overcome a partial deficiency of potassium, although sodium could to a considerable extent. This is shown once more in the present instance by the series in which the customary source of nitrogen, calcium nitrate, was used. When this was substituted by magnesium nitrate, however, the excess of magnesium was so great that the addition of calcium chlorid ($CaCl_2$) materially increased the transpiration and root growth, although the weight of tops in this case was not increased. In those series containing a large excess of magnesium the main roots were shorter and the number and extent of the lateral branches were very much reduced as compared with the series where there was a larger proportion of calcium. The accompanying illustrations (figures 1 and 2, opposite page 278) give an idea of the difference in root development.

To substantiate the somewhat remarkable results outlined in table XX, two other similar experiments were conducted, which were extended, however, in order to ascertain the effect of adding a small amount of sodium hydroxid to the magnesium-nitrate series in view of magnesium being less basic than calcium. The results are comprised in table XXI. It will be observed that the two nitrates affected the seedlings in much the same way as was shown before. Concerning the effect of the sodium hydroxid in connection with magnesium nitrate, it may be seen that there was very little influence when the full amount of potassium was present. As might be expected, in view of the ability of sodium to supplement advantageously a deficient amount of potassium, the reduction in the potassium to 8 ppm. resulted in a smaller depression in both transpiration and green weight in case of the series to which sodium hydroxid had been added. Likewise the addition of sodium in sodium chlorid could not have been expected to have increased the growth to such an extent in the magnesium-nitrate series to which sodium hydroxid had been added as in those to which it had not. The numbers representing the relative transpiration and green weight were larger when sodium hydroxid was present with 8 ppm. of potassium supplemented

by calcium chlorid than when it was absent. This may be attributed to the beneficial effect of the sodium itself. The relative green weights, especially, were larger than in the similar series containing calcium nitrate, and probably for the same reason. It can scarcely be claimed that there was any advantage derived from the alkalinity of the sodium hydroxid either upon the root development or otherwise.

TABLE XXI.

The Effect of Sodium on Wheat Seedlings when used with Various Ratios of Calcium to Magnesium.

SPECIAL ADDITIONS.	FROM EACH BOTTLE.				RELATIVE.			
	Transpiration.		Green weight.		Transpiration.		Green weight.	
	Expt. I.	*Expt. II.*	*Expt. I.*	*Expt. II.*	*Expt. I.*	*Expt. II.*	*Expt. I.*	*Expt. II.*
42 ppm. N. in $Mg(NO_3)_2$								
32 ppm. K. in K Cl........	143 133	209 174	5.83 5.30	6.82 5.72	100	100	100	100
8 ppm. K. in K Cl........	85 96	119 100	3.57 3.72	3.96 3.51	65	57	65	60
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl......	117 135	125 150	4.30 4.77	4.24 4.71	91	72	82	71
8 ppm. K. in K Cl, and 12 ppm. Ca. in $Ca Cl_2$......	118 118	165 180	4.02 3.95	4.42 4.50	86	90	72	71
42 ppm. N. in $Mg(NO_3)_2$, made alkaline, $\frac{N}{500}$, by sodium hydroxid.								
32 ppm. K. in K Cl........	147 141	174 207	6.21 5.42	5.67 5.93	105	99	104	93
8 ppm. K. in K Cl........	105 104	130 137	4.11 3.99	4.29 4.13	76	70	74	67
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl......	96 106	140 141	3.94 4.00	4.45 4.57	73	74	71	72

Table XXI.—Concluded.

The Effect of Sodium on Wheat Seedlings when used with Various Ratios of Calcium to Magnesium.

Special Additions.	From Each Bottle.				Relative.			
	Transpiration.		Green weight.		Transpiration.		Green weight.	
	Expt. I.	*Expt. II.*	*Expt. I.*	*Expt. II.*	*Expt. I.*	*Expt. II.*	*Expt. I.*	*Expt. II.*
8 ppm. K. in K Cl, and ppm. Ca. in Ca Cl_2......	128 135	208 195	4.40 4.45	5.50 5.19	95	106	79	85
42 ppm. N. in $Ca(NO_3)_2$ 32 ppm. K. in K Cl........	178 160	285 281	5.30 5.24	6.11 5.84	123	148	95	95
8 ppm. K. in K Cl........	138 139	191 191	4.12 4.21	4.50 4.28	100	100	75	70
8 ppm. K. in K Cl, and 14 ppm. Na. in Na Cl....	167 172	258 239	4.76 4.69	5.49 5.05	123	130	85	83
8 ppm. K. in KCl, and 12 ppm. Ca. in Ca Cl_2......	132 127	198 175	3.86 3.79	4.44 4.06	94	98	69	68

At the close of the last period of the experiment the solutions in the three series to which 32 ppm. of potassium had been added were diluted to the original volume, and 50 cc. of the same were titrated against $\frac{N}{100}$ sulfuric acid with methyl orange as indicator. In the magnesium-nitrate series, without sodium hydroxid, 10.5 cc. of the acid were required to neutralize; with sodium hydroxid, 11.5 cc.; and in the calcium-nitrate series, only 6 cc. It may be seen, therefore, that, in spite of the less basic nature of the magnesium, the nutrient solution had become more alkaline with magnesium nitrate than with calcium nitrate; probably because the seedlings absorbed the magnesium less readily than the calcium.

The depression of the root development and transpiration, which has accompanied the replacement of calcium nitrate by magnesium

nitrate, was so marked as to make it seem probable that the transference of the seedlings from one solution to the other might give some interesting results. The effect of such transference in the case of the full nutrient solutions is shown by table XXII.

TABLE XXII.

The Effect on Wheat Seedlings of their Exchange between Magnesium-Nitrate and Calcium-Nitrate Nutrient Solutions.

	From Each Bottle.			Relative.	
	Transpiration.		Green weight.	Transpiration.	Green weight.
	Apr. 17–20.	Apr. 21–24.	Apr. 24.	Apr. 21–24.	
42 ppm. N. in $Mg(NO_3)_2$					
Not transferred..........	60 60	123 125	5.9 5.6	100	100
Trans. to $Ca(NO_3)_2$ sol. April 21................	53 49	124 113	5.3 5.2	96	91
Trans. to $Ca(NO_3)_2$ sol. April 17................	55 51	143 150	5.5 5.2	118	93
42 ppm. N. in $Ca(NO_3)_2$					
Not transferred..........	73 73	174 174	5.6 5.2	140	94
Trans. to $Mg(NO_3)_2$ sol. April 21................	75 75	165 165	5.6 5.8	133	99
Trans. to $Mg(NO_3)_2$ sol. April 17................	70 72	157 145	5.6 5.4	122	96

The green weight from the different series was about the same in all cases. The transpiration was 40 per cent. greater with the calcium nitrate than with the magnesium nitrate, and there was a corresponding difference in root development. The seedlings which

were transferred on April 17 from the magnesium-nitrate to the calcium-nitrate solution increased markedly in transpiration and root development; whereas the reverse transference resulted in a depression of transpiration and a limitation of the root growth. Even a transference from the magnesium-nitrate solution for only the last few days of the experiment resulted in an improvement in the root system and a slightly greater percentage increase in transpiration.

The results in table XXIII, which will be considered next, show the influence exerted by a change in the relation between calcium and magnesium when used in connection with a deficient amount of potassium.

TABLE XXIII.

The Effect on Wheat Seedlings of Different Ratios of Magnesium to Calcium in the Nutrient Solution.

SPECIAL ADDITIONS.	FROM EACH BOTTLE.		RELATIVE.	
	Transpiration.	Green weight.	Transpiration.	Green weight.
42 ppm. N. in Mg $(NO_3)_2$ 32 ppm. K. in K Cl........	207 173	5.76 5.71	100	100
8 ppm. K. in K Cl.........	125 103	3.60 3.43	60	61
8 ppm. K. in K Cl, and twice usual amt. Mg SO_4	90 89	3.14 3.25	47	56
8 ppm. K. in K Cl, and no Mg SO_4................	116 127	3.36 3.90	64	63
8 ppm. K. in K Cl, and 12 ppm. Ca. in Ca Cl_2......	157 163	3.88 3.90	84	68
42 ppm. N. in Ca $(NO_3)_2$ 32 ppm. K. in K Cl........	274 269	5.57 5.96	143	101

As usual, the transpiration was about 40 per cent. greater with magnesium nitrate than with calcium nitrate; whereas the green weights remained alike. (Compare the first and last series).

When the usual amount of magnesium sulfate was doubled, the relative green weight was depressed from 61 to 56, and the transpiration from 60 to 47. For similar reasons the entire elimination of magnesium sulfate seemed to result in a slight relative increase in green weight and transpiration.

The addition of calcium chlorid increased the relative transpiration from 60 to 84, and relative green weight from 61 to 68. Undoubtedly this was not because the calcium partly took the place of potassium, for experiments referred to previously have shown that this does not occur, but rather because of its well-recognized property of counteracting the effect of relatively large amounts of magnesium.

In order to ascertain whether the amounts of magnesium salts which have been used were of themselves toxic to the seedlings, the following experiment was conducted, in which the seedlings were allowed to grow as long as they would in the absence of the other necessary nutrients. The results appear in table XXIV.

TABLE XXIV.

The Growth of Wheat Seedlings with only the Magnesium Salts, and also with only the Calcium Salts.

	Length of roots, inches.	Green weight of tops.	Relative green weight.
Distilled water	5.0 4.5	1.06 .97	100
96 ppm. $Mg\,SO_4$	3.5 4.5	1.14 1.26	118
96 ppm. $Mg\,SO_4$ and 223 ppm. $Mg(NO_3)_2$	2.0 2.0	1.05 1.17	109
58 ppm. $CaH_4(PO_4)_2$ and 244 ppm. $Ca(NO_3)_2$	8.5 7.5	1.59 1.78	166

The roots in the distilled water showed less tendency to branch, and were not so stocky as those in only the magnesium-sulfate solution. When both magnesium salts were present the roots were not only shorter and slimmer than those in any other series, but were of a brownish-green color. The roots in the solution containing the calcium salts were normal for a solution containing no potassium. It is evident that the calcium salts as they have been used ordinarily in the foregoing experiments are, even by themselves, non-toxic; but that when only the magnesium sulfate and nitrate are present, in the same amounts as used in certain series of the foregoing experiments, there is a poisonous action on the roots. According to Osterhout's definitions* these particular magnesium salts were therefore in too great concentration to constitute a part of a true nutrient solution (one in which no salt is in greater concentration than that which would be non-toxic if the salt were used alone), but form a portion of a "balanced solution" when accompanied by certain ingredients possessing the property of overcoming their toxicity. The addition of calcium fulfills this requirement, and the increase in growth caused by supplementing a deficient amount of potassium by calcium in those cases where much magnesium was present was due to its offsetting the depressing effect of the magnesium and not to its having the property, which sodium possesses, of partly replacing potassium.

In the comparisons of the magnesium-nitrate and calcium-nitrate series which have been presented in foregoing tables it was observed that the weight of tops was the same in both cases, but that the transpiration was usually about 40 per cent. greater with the calcium nitrate. This increase was accompanied by a similar increase in root development. It was very evident that in this instance the increased transpiration was not indicative of greater leaf surface, as has been claimed, but that it was more truly a measure of root development. The roots looked healthy in the magnesium-nitrate series, and had an abundance of root hairs; but, as has been said, they were not so well branched nor nearly so heavy as in the cal-

* Bot. Gaz. 44, 259.

cium-nitrate series. If the root system was limited by some unfavorable action of the particular nutrient solution, the tops must have escaped any disturbance, if their weight can be accepted as a criterion. It is possible that the leafy portions of the seedlings were protected from an unfavorable nutrient solution by the curtailment in root development and consequent reduction in the amount of absorbed solution and transpired water. It is scarcely probable that the greater development of roots was due to the calcium in the calcium-nitrate solution, in view of the fact that the magnesium-nitrate solution itself contained calcium in the mono-calcium phosphate which was used as the source of phosphorus.

It might be claimed that the increase in growth, which has so continually accompanied the addition of sodium when seedlings were grown for only about three weeks, would not be maintained if the experiments were so arranged that longer periods of growth could be secured.

To obtain data on this point, six paraffin receptacles were made, each of which had a capacity of about 1,200 cc. and which accommodated corks five inches in diameter. With these receptacles no claim could be made that the sodium was beneficial because it liberated potassium. The general nutrients and the special applications, potassium and sodium chlorids, were the same as had been used with the smaller receptacles. Two of the vessels received an abundance of potassium; two, a deficient amount of potassium; and two, this same amount plus sodium. The transpiration was taken approximately, during the progress of the experiment, as a measure of the amount of deficiency of potassium which was brought about in certain series. About once a week the solutions were entirely removed from the receptacles, and the latter were thoroughly washed before the fresh solution was placed in them. In the first experiment twenty wheat seedlings were suspended, as usual, from each cork, but eventually the seedlings receiving the nutrient solution containing a liberal amount of potassium had produced such an abundance of roots that there was a solid mass filling the receptacle.

After this the full potassium series made relatively less growth, and it appeared as though fewer plants would have been desirable. In the second experiment only ten seedlings were grown in each receptacle. The experiments were not continued in either case beyond the period of growth when the internodes elongate rapidly. The results are recorded in table XXV.

TABLE XXV.

Effect of Sodium on Wheat Plants Grown until the Time of "Shooting."

Special Additions.	Weight of Oven-dry Plants, in Grams. Tops.	Roots.	Total.	Relative weight, total.
Expt. I (Nov.-Feb.)				
Full potassium	13.7 13.1	7.3 6.8	21.0 19.9	100
Deficient potassium	11.8 11.6	3.6 3.5	15.4 15.1	75
Deficient potassium, plus sodium	13.2 13.9	4.5 4.6	17.7 18.5	89
Expt. II (Mar.-June)				
Full potassium	12.0 12.8	3.7 3.7	16.5 16.5	100
Deficient potassium	8.5 9.6	2.7 2.2	11.2 11.8	71
Deficient potassium, plus sodium	11.9 10.8	3.7 3.0	15.6 13.8	91

In these two experiments the plants were allowed to grow until fifteen to twenty times the usual amount of material had been produced. Potassium was not withheld from the series receiving the small amount to such an extent as to interfere with the healthfulness

of the plants; and yet, when the small amount of potassium was supplemented by sodium, the plants were 19 per cent. heavier in the first experiment, and 30 per cent. heavier in the second, than when the same amount of potassium was unaccompanied by sodium.

SUMMARY.

The present article is a record of the conclusion of a special line of work bearing upon sodium as a plant nutrient, the first part of which was described in the preceding annual report of this Station, pages 299 to 357. Therefore the present summary will include the main features of the work as a whole.*

The special object of the work was to ascertain with certainty, mainly by means of water-culture experiments carried on under varying conditions, whether the beneficial effects which had been especially noticeable in the field with certain crops, as a result of a liberal application of sodium to plats containing but a small amount of available potassium, was due, in part, at least, to a direct action of sodium as a plant nutrient.

The greater part of the experimenting was done with wheat seedlings, which were allowed to grow a few weeks in a solution containing all of the nutrients, modified in most cases so as to furnish four series which may be characterized as follows: 1, optimum potassium without sodium; 2, deficient potassium without sodium; 3, deficient potassium with sodium; 4, deficient potassium with extra calcium. Likewise the optimum amount of potassium was at first supplemented with sodium, and again with an extra amount of calcium, for comparison with optimum potassium alone.

When the potassium was abundant there was no increase in the growth of seedlings caused by the addition of either sodium or an equivalent amount of extra calcium.

When the potassium was withheld to such an extent that the growth of the seedlings was depressed about a third within a period

* In the references, given in parentheses in bold-faced type, **20** refers to the preceding annual report, and **21** to this report.

of three weeks, an addition of sodium in an accompanying series resulted in an increase in the production of seedling tops equal to 10 per cent. or more; in a series differing only by an addition of extra calcium, however, an increase in growth was not secured.

The chlorids, sulfates, and carbonates of potassium and sodium were used in different experiments; and likewise the chlorid, and sulfate of calcium.

The increase of transpiration was usually less than that of green weight, when the potassium was increased or the sodium added, especially with the carbonates. (**20**, 344–345.)

Experiments with millet, oats, barley, and rye seedlings showed, as with wheat, that sodium was beneficial when used with a deficient amount of potassium. Its effect with rye, however, was less than with the other cereals, direct comparisons having been made with wheat and with barley seedlings. (**21**, 243–248.)

Aside from the special additions, the salts generally employed in the foundation solution were as follows: calcium nitrate, magnesium sulfate, mono-calcium phosphate and ferric nitrate. These were used in widely varying amounts in order to study the influence of the variations on the specific effect of sodium. (**20**, 319–330; **21**, 255–272.)

With an exceptional nutrient solution containing a large proportion of magnesium to calcium, the addition of an extra amount of calcium in connection with a deficient amount of potassium resulted, as with sodium, in a greater weight of seedlings. Undoubtedly this was due, however, to the property possessed by calcium of counteracting the injurious influence of too large a proportion of magnesium, rather than to an ability to partly replace potassium. (**21**, 272–281.)

The effect of too large a proportion of magnesium to calcium became apparent principally in a very marked reduction in the transpiration and root growth, rather than in the weight of tops. The addition of more calcium to such a nutrient solution had a particularly beneficial effect upon the development of roots, the influence

of sodium under such conditions not being so marked in this respect. (**21**, 272–278.)

Increasing the amount of sodium to two and three times that which was equivalent to the partially replaced potassium, the amount ordinarily used, did not greatly change the extent of gain when compared with the growth resulting from the deficient amount of potassium alone. (**21**, 251–252.)

During a given time less potassium was absorbed by the seedlings when the potassium was supplemented by sodium than when it was not. In other words, sodium was a conserver of potassium. (**20**, 347–354.)

In two experiments wheat was grown for about four months in solutions contained in paraffin receptacles. In one series there was a deficiency of potassium great enough to cause about 30 per cent. depression in the weight of the entire plants as compared with the series receiving optimum potassium. In another series the addition of sodium to the deficient amount of potassium increased the product in one experiment 19 per cent., and in the other, 29 per cent. (**21**, 281–283.)

With certain plants, sodium has proved beneficial in sand culture, when the potassium was somewhat deficient. (**20**, 345–356; **21**, 219–250.)

The experimental work seems to show that the beneficial effect of sodium was not attributable to the increase of osmotic pressure, to a change of the acidity or alkalinity of the nutrient solution, nor to overcoming the effect of unfavorable quantitative relations of the nutrients in solution; although without doubt sodium salts under certain circumstances act advantageously in these ways.

Apparently certain of the uses of potassium, with some plants at least, may be performed by sodium; although there are certain principal functions of potassium which cannot be performed by any other element. If the amount of potassium is insufficient for the performance of these exclusive functions, probably maximum growth cannot be secured with any amount of sodium which may be added.

THE RELATIVE TOXICITY OF FERROUS SULFATE TO BARLEY AND RYE SEEDLINGS.

BURT L. HARTWELL AND F. R. PEMBER.

It is generally claimed that the presence of any considerable quantity of soluble ferrous salts in the soil is detrimental to the growth of plants. According to Boiret and Paturel* the action of the acid liberated as a result of the natural decomposition of these salts might serve as an explanation of the sterility which had been attributed to the salts themselves. They cite that the passage of ferrous sulfate, for example, to the basic ferric sulfate, results in the liberation of three-fourths of the sulfuric acid as shown by the following equation: $4(FeO.\ SO_3)+O_2+3H_2O=(Fe_2\ O_3)_2\ SO_3+3H_2\ SO_4$.

The marked benefit resulting from applications of lime to many of our upland soils led quite early to the examination of the Station soil for soluble iron compounds; and, while water failed to extract any appreciable amount of iron, many observations have been made from time to time which indicated that certain of the iron compounds in the soil were very easily decomposed. The ashes of the plants which were grown upon certain plats were quite brown from the presence of iron. This was particularly noticeable in one instance in the case of the tobacco plant, except where lime was applied, when the ash was of a much lighter color. As much as three-fourths of the ash associated with the extracted humus of these sôils has been found to consist of ferric and aluminic oxid, apparently mostly ferric

* Ann. Agron. 18, 417–440 (1892).

oxid. Certain data regarding the compounds of iron in the soils in question may be found in an earlier report.*

In connection with the experiments for ascertaining the relative effect of liming upon different plants, which have been carried on during a number of years at this Station, it was found that, among the ordinary cereals, barley and rye were very differently affected. Under conditions resulting in no benefit to rye from liming, the crop of barley would be increased usually from 100 to 200 per cent. As these cereals are admirably adapted for water cultures with seedlings, it seemed to the authors that some definite light might be thrown by this method upon the causes which make it necessary to add alkaline material to the soil before satisfactory crops of certain plants can be grown.

In the last annual report of this Station the relative effect upon cereal seedlings of the addition of acid to a full nutrient solution, was studied, with particular attention to barley and rye, which are so differently influenced by liming.† "The water-culture experiments showed that barley seedlings were *not* more susceptible than rye seedlings to injury from acidified nutrient solutions, even though the field results proved that barley received very much more benefit than rye from liming."

The same nutrient solution and the same method of water culture as was described in connection with the work just mentioned were used in determining the relative effect of ferrous sulfate upon barley and rye seedlings, which is the subject of this article. It was considered possible that easily decomposable ferrous compounds might be a troublesome factor in soils in need of lime, and that, if such were the case, the two plants in question, which differ so materially in their susceptibility to the disturbing factors in such soils, might be differently affected.

The ferrous sulfate which was used was the so-called c. p. salt,

* Ann. Rpt. R. I. Agr. Expt. Sta. 18, 247–250 (1905).

† Ann. Rpt. 20, 358–380 (1907).

precipitated by alcohol, and was purchased from the J. T. Baker Chemical Co.

In order to obtain a preliminary idea of the toxic limits of ferrous sulfate, the following experiment was conducted:

Effect of Ferrous Sulfate on Wheat Seedlings.

Strength of solution as concerns ferrous sulfate.	Transpiration per bottle, 10 plants, in grams.	Green weight per bottle, 10 plants, in grams.	Relative transpiration, 20 plants.	Relative green weight, 20 plants.
None	178 170	5.9 6.1	100	100
$\frac{N}{5000}$	125 171	4.5 5.3	85	82
$\frac{N}{2500}$	124 127	4.2 4.2	71	70
$\frac{N}{1667}$	116 106	3.6 3.5	62	60
$\frac{N}{1250}$	73 89	2.8 3.1	46	50
$\frac{N}{837}$	54 54	2.1 2.4	30	38
$\frac{N}{500}$	43 44	2.2 2.0	24	35

The preceding table shows that the transpiration and weight of the green seedlings decreased with each successive increase in the amount of ferrous sulfate. In the last two series the roots scarcely penetrated the solution and were very much stunted; they were rusty in appearance, due to the iron compound which was deposited upon them.

Effect of Ferrous Sulfate on Wheat and Rye Seedlings.

Strength of solution as concerns ferrous sulfate.	Transpiration per bottle, 10 plants, in grams.		Green weight per bottle, 10 plants, in grams.		Relative transpiration, 20 plants.		Relative green weight, 20 plants.	
	Wheat.	*Rye.*	*Wheat.*	*Rye.*	*Wheat.*	*Rye.*	*Wheat.*	*Rye.*
None.......	194 197	157 193	6.6 6.5	5.5 5.7	100	100	100	100
$\frac{N}{2500}$.......	122 130	118 125	4.2 4.1	3.5 3.5	64	70	63	64
$\frac{N}{1250}$.......	100 88	98 83	3.2 3.0	2.7 2.7	48	51	47	49

The single experiment which is recorded in the preceding table does not indicate any marked difference in the effect of ferrous sulfate on the two kinds of seedlings.

In the remainder of the tests the comparisons will be made with only rye and barley, as these plants are very different in respect to the effect of lime upon them.

According to the first two experiments in the following table, barley was more susceptible than rye to injury from the ferrous sulfate. The third experiment, however, indicates the reverse.

It may be noticed that the transpiration from the rye seedlings was generally greater than from the barley seedlings within the same period of time; in spite of the fact that a greater green weight was produced by the barley in the nutrient solution itself.

Effect of Ferrous Sulfate on Barley and Rye Seedlings.

Strength of solution as concerns ferrous sulfate.	Transpiration per bottle, 10 plants, in grams.		Green weight per bottle, 10 plants, in grams.		Relative transpiration, 20 plants.		Relative green weight, 20 plants.	
	Barley.	*Rye.*	*Barley.*	*Rye.*	*Barley.*	*Rye.*	*Barley.*	*Rye.*
Expt. I.								
None.	195 186	224 208	6.8 6.8	5.7 5.8	100	100	100	100
$\frac{N}{2500}$	116 133	175 182	5.2 5.0	4.7 4.8	65	82	74	83
$\frac{N}{1250}$	99 104	142 163	3.8 3.8	3.6 4.0	54	70	55	66
$\frac{N}{937}$	86 91	120 109	2.8 3.4	2.8 3.2	46	53	45	52
Expt. II.								
None.	153 153	170 168	6.4 6.5	5.5 5.3	100	100	100	100
$\frac{N}{2500}$	100 117	134 128	3.9 4.5	4.2 3.8	71	78	65	75
$\frac{N}{1250}$	84 88	119 97	3.6 3.7	3.5 3.2	55	64	56	62
Expt. III.								
None.	189 185	194 189	7.1 6.9	6.5 5.9	100	100	100	100
$\frac{N}{2500}$	153 132	130 134	6.4 5.5	4.6 4.4	76	69	85	72
$\frac{N}{1250}$	102 133	107 112	4.2 4.5	3.6 3.4	57	57	62	56

It seemed possible, if the rye seedlings were allowed to grow until they had attained a weight equal to that of the barley, that the injurious effect of the ferrous sulfate would then be less marked.

The following experiment was conducted to throw light upon this point:

Relative Effect of Ferrous Sulfate on the Transpiration of Rye Seedlings at two Stages of Growth.

Strength of solution as concerns ferrous sulfate.	Transpiration per bottle, 10 plants, in grams.		Green weight per bottle, 10 plants, in grams.	Relative transpiration, per bottle, 20 plants.		Relative green weight, 20 plants.
	Feb. 11–18.	Feb. 19–25.	Feb. 25.	Feb. 11–18.	Feb. 19–25.	
None..........	201 189	357 336	9.2 9.3	100	100	100
$\frac{N}{1500}$..........	137 147	265 272	7.2 7.7	73	77	81
$\frac{N}{1250}$..........	116 135	221 235	6.6 6.9	64	66	73

In the preceding table the transpiration is given for two periods. At the end of the first period the green weights in the series to which ferrous sulfate was not added would have equalled about six grams per ten plants, as was usual at this stage of growth of the rye seedlings. Barley seedlings during the same time usually weighed six and one-half to seven grams.

As may be seen, the rye seedlings in the present instance were allowed to grow until the green weight in the first series was about nine grams.

The relative transpiration during the two periods was about the same, notwithstanding that the seedlings were allowed to attain a greater weight than the barley in any of the experiments. This experiment indicates that there would not have been much change in the relative effect of ferrous sulfate in the preceding experiments had the rye been allowed to grow for a little longer time than the

barley, in order to have produced green weight equal to that of the barley.

In the final comparison of the two seedlings, which is recorded in the following table, three bottles instead of two were included in each series, in order that a larger number of plants might be included in the average:

Effect of Ferrous Sulfate on Barley and Rye Seedlings.

Strength of solution as concerns ferrous sulfate and sulfuric acid.	Transpiration per bottle, 10 plants, in grams.		Green weight per bottle, 10 plants, in grams.		Relative transpiration, 30 plants.		Relative green weight, 30 plants.	
	Barley.	*Rye.*	*Barley.*	*Rye.*	*Barley.*	*Rye.*	*Barley.*	*Rye.*
	240	266	6.9	6.6				
None..............	244	280	7.5	7.0	100	100	100	100
	227	258	7.2	6.2				
	163	149	5.7	3.9				
$\frac{N}{2500}$, $Fe SO_4$........	186	78	6.4	3.3	76	45	82	55
	195	139	5.7	3.5				
	134	88	4.5	2.7				
$\frac{N}{1250}$, $Fe SO_4$........	125	113	4.6	2.6	57	36	65	40
	149	89	5.1	2.4				
	216	......	6.4	......				
$\frac{N}{2500}$, $H_2 SO_4$........	188	......	6.2	......	83	......	86	......
	192	......	6.1	......				
	130	......	3.8	......				
$\frac{N}{1250}$, $H_2 SO_4$........	128	......	4.1	......	53	......	54	......
	118	......	3.8	......				

It may be seen in the preceding table that the rye seedlings were injured to an unusual extent by the ferrous sulfate, and much more than the barley seedlings.

In the foregoing experiment two additional series, to which sulfuric acid was added, were conducted simultaneously with the others, in the case of barley, so that a strict comparison might be secured of

the relative effect of sulfuric acid and ferrous sulfate of the same normality. When added to the nutrient solution in amounts equal to $\frac{N}{2500}$ the average transpiration and green weight were depressed more by the sulfuric acid than by the ferrous sulfate; while with the $\frac{N}{1250}$ solutions the reverse was true. It may be seen that the results with the individual bottles were frequently about the same with the two materials. For other data regarding the effect of sulfuric acid in a like nutrient solution, see page 376 of the preceding annual report. It seems not improbable that the suggestion of Boiret and Paturel, referred to earlier in this article, might be applied in the present instance; and that the injurious action of the ferrous sulfate was due largely to the acid radical.

For ease of comparison the relative transpiration and green weight with ferrous sulfate, as given in the preceding experiments, are brought together in the following compilation. The values on the same line were obtained at the same time and are strictly comparable. The transpiration and green weight from the series receiving the nutrient solution without the addition of the ferrous sulfate are represented by 100, and the values given are based upon this standard:

	Transpiration.		Green weight.	
	Barley.	*Rye.*	*Barley.*	*Rye.*
$\frac{N}{2500}$ ferrous sulfate	65	82	74	83
	71	78	65	75
	76	69	85	72
	76	45	82	55
$\frac{N}{1250}$ ferrous sulfate	54	70	55	66
	55	64	56	62
	57	57	62	56
	57	36	65	40

It may be seen readily, by an inspection of these figures, that no conclusion is justified as to whether one or the other cereal was most

injured by the addition of ferrous sulfate to the nutrient solution. It seemed apparent, in case a larger number of comparisons had been made, that now one cereal and then the other would be affected the more, and that in the end no great difference would exist between the average of the results.

In conducting the experiments with ferrous sulfate precautions were taken to prevent oxidation up to the time when the seedlings were placed in the solutions. The water was boiled, and cooled rapidly, just prior to its use in making the nutrient solution for each successive change; and the iron salt was added immediately before the seedlings were suspended in the solutions.

Judging from the rusty appearance of the roots when the stronger solutions of ferrous sulfate were used, it seemed probable that the ferrous sulfate was quite readily oxidized in the presence of the growing seedlings. Fresh solutions were supplied about every four days. The absolute effect of a given strength of ferrous sulfate would be expected to depend largely upon the frequency of the renewed applications; and doubtless also upon the nature of the nutrient solution. In the present work the object was not so much to determine the toxicity of a given solution as to ascertain its relative effect on barley and rye seedlings.

These experiments do not prove that the effect of ferrous sulfate is markedly different with barley and rye seedlings. This is in marked contrast to the effect of lime in the field on these two cereals.

Division of Animal Breeding and Pathology.

18

REPORT OF THE DIVISION OF ANIMAL BREEDING AND PATHOLOGY.

LEON J. COLE.

The work of this division during the past year has been a direct continuation of that of the year preceding.* There have, however, been several new lines of work inaugurated.

BLACKHEAD DISEASE OF TURKEYS.†

During the last months of the preceding fiscal year (spring of 1907) plans were made and arrangements perfected for pushing the experimental work on blackhead, especially that bearing on the matter of transmission of the disease. During July and August these experiments were carried out, and at the same time, in order to be able to give more attention to the pathological side of the problem, a temporary assistant was found to help with the work in the laboratory during the summer. The division was fortunate in securing for this position Dr. Philip B. Hadley, at that time a graduate student in Brown University. The laboratory examinations soon revealed the presence of large numbers of organisms belonging to the genus *Coccidium*, in various stages, in the great majority of turkeys dying of blackhead, and further investigation led to the conclusion that the parasite described by Smith, and called by him *Amoeba meleagridis*,

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* See Twentieth Ann. Rept. R. I. Agr. Expt. Sta., 1906–1907 (1908), pp. 279–287.

† Until June 30, 1908, these investigations were carried on in coöperation with the Bureau of Animal Industry, U. S. Department of Agriculture.

was in reality a stage in the life cycle of this *Coccidium*. These findings modified somewhat the course of the investigations, which now centered about this causative organism, and consisted in a study of its life cycle, its resistance to injurious substances and conditions, its occurrence in and effect on other birds and mammals, and the means by which it might, in nature, be transmitted from one bird to another. A preliminary statement of these results was made at the meetings of the American Society of Zoölogists and the American Society of Bacteriologists in December, and was later published in Science.*

During the winter the work consisted in the examination of such birds as died of the disease, together with the sectioning and microscopic study of the diseased organs. In the spring the field investigations were taken up where they had been dropped the previous summer, a number of improvements in the methods of conducting them being made as a result of previous experience. On June 1, 1908, Dr. Hadley again came into the laboratory and resumed his work where he had left it.

A report of the investigations upon this disease at this Station the past two years has now been prepared. It should, perhaps, be mentioned here that a report at this time is only a report of progress. The ultimate object of the investigations is to be able to cure, or at least to control, this disease; and while determining the real character of the organism which causes it and understanding its life history is a great step toward this end, it may nevertheless be a long way from its final attainment. The problem is rendered especially difficult by the nature of the causative organism; if it could be grown upon artificial media and isolated in pure cultures like the bacteria, the investigation would be greatly simplified. Comparative scarcity of material in the way of turkeys at the right age, together with other complications, threaten to make the task a long one; but it is felt, nevertheless, that a distinct gain has been made, and continued effort should result in still further advance in the near future.

* Cole, Leon J., and Philip B. Hadley. "Blackhead, a Coccidial Disease of Turkeys," Science, N. S., vol. 27, No. 704, 1908, p. 994.

LEG WEAKNESS.

Poultrymen who use artificial methods of rearing have been much troubled by a condition of their young birds marked by weakness of the legs, which results in inability to stand, difficulty in breathing, and is terminated by death. This tendency in brooder-reared turkeys has been a serious drawback to the experiments with blackhead, where it was desired to raise the poults for as long a period as possible on board floors. The trouble has, like so many other poultry diseases, been ascribed variously to inherited weakness, to improper feeding, to lack of exercise and ventilation, to "bottom heat," and various other causes. Some attempt has been made, rather incidentally, to separate out and test some of these various factors, and results have been obtained which add something to the knowledge of the conditions required, even if they do not settle the question. It is proposed to publish these results separately.

BREEDING WORK WITH PIGEONS.

The breeding work with pigeons was begun early in 1907. The immediate problem taken at the start was the determination of some of the laws relating to the inheritance of color in Tumbler pigeons. It was felt that results along this line would be of considerable general theoretical value, and, furthermore, that they might have direct and immediate application for the fancier. The reason that "fancy points" and not "utility characters" were chosen was that they are so much more definite, and hence give better opportunity for reliable conclusions to be drawn from a relatively smaller amount of data.

It should not be forgotten, however, that results which at first glance appear to be entirely theoretical and abstruse may prove at a future time to have a direct application to practical needs, and to be of the greatest value from a utilitarian standpoint. The history of science and economics has furnished numberless examples of just this thing. The breeding of guinea-pigs might seem to many to be a matter which could have no possible relation to agricultural uses,

but the general laws deduced in this way may prove of inestimable value to the stock breeder. Thus Professor Castle, of Harvard University, has just announced the production of an entirely new and unknown color variety of the guinea-pig.* The interest does not lie so much in this fact as it does in that he was able to predict the results, and went at it definitely to obtain a type which, upon theoretical grounds, he should be able to produce. This he did in as definite a manner as the chemist who puts together certain chemicals, having properties with which he is familiar, and produces some substance which he may never have seen before, but whose properties he has been able to predict. Just so Professor Castle was working with guinea-pigs whose ancestry he knew, and, furthermore, he knew the laws governing the inheritance of their color patterns and pigments. Perhaps the most striking feature is that, making the proper crosses, the new predicted variety was produced in the *second generation* and is a permanent variety, that is, one which will "breed true." There is no basis for computing the time it would have taken anyone not familiar with the laws governing the inheritance of coat-color to produce this result, further than that guinea-pigs have been bred for untold generations and the variety was unknown, hence had in all probability never been produced. And now as to the application of this to practical breeding. When we know the characters in our horses and cattle and swine which obey these same laws we are at once in a position to breed for definite results, and are, moreover, withheld from attempting to produce the unattainable, since we may know certain results which can be obtained and others which cannot. The value of using mice and guinea-pigs and pigeons instead of horses and cattle in order to discover these laws may now be seen,—they are cheaper, easier to handle and keep, breed oftener, and in many cases produce more young at a time, so that results are obtained much more rapidly and economically than would be the case if the larger domesticated animals were employed.

* Castle, W. E., A new color variety of the guinea-pig. Science, N. S., Vol. 28, 1908, No. 712 pp. 250–252.

Certain results which have already become apparent from the pigeon-breeding are of interest, and illustrate, also, the value which the work may possess for the fancier. Thus if red Tumblers and black Tumblers, which have been found to come true to color when bred amongst themselves, are crossed, the birds of the first generation are all black with reddish or buffy tips on the feathers. In the later molts, however, these reddish tips may be lost, in which case the bird is indistinguishable from its black parent. If now two of these offspring be mated, most of their offspring will be like themselves when young, *i. e.*, black with buffy tips; but *one-fourth* of the offspring in this second filial generation will be red.* These red birds should breed true, whereas from the blacks of this generation should be produced both blacks and reds. These are matters which are still to be tested. The above results conform very closely to the requirements of Mendel's Law, but present certain features which merit further study. This particular case is cited at this time to indicate the trend of the work.

Other problems have been kept in mind and carried along in conjunction with the breeding. Owing to the difficulty in distinguishing the sexes of pigeons, especially before they are old enough to mate, squab raisers often are troubled by finding that they have saved for breeding purposes an excess of one or the other sex, usually of males (?), whereas it is their desire to have approximately an equal number of each. No physical characters appear to be present in pigeons by which the sex can be determined infallibly, and especially is this true of the young birds. The squab raiser must, of course, dispose of his birds when they are very young, and before he can make use of their behavior in determining their sex. It appears to be widely believed among pigeon breeders that the first egg of the complement of two which is laid gives rise to a male bird, while the second produces a female. This, if true, would be a fact of great importance and extreme interest, but unfortunately it is shown by the keeping

* In the results which have actually been obtained to date, the proportion of red birds in F_2 has been somewhat greater than 1:3; but the total numbers as yet obtained are too small to make this significant.

of careful records that such is not the case. On the contrary, the question of sex appears to be a matter of chance, as is the case in most animals. These results will soon be published in detail, together with other matters on the time of laying, period of brooding, etc., which have come out in the course of the work.

Coöperative Experiments with Bees.

Whereas most of the animals which man has domesticated have been greatly improved by fortuitous or intelligent selective breeding, little or no progress has been made in this line with bees. This is because of the attendant difficulties, chief of which are, first, the fact that the workers are the individuals in which it is desirable to make the improvements, whereas the breeder cannot make this change directly upon the workers, but must do it through the sexually perfect members of the colony, the queens and drones; and second, the difficulty in controlling the mating of the queen. Progress upon the first problem is dependent upon a solution of the second. Bee breeders have usually attempted this by having in their yards drones of only the kind with which it is desired to have the virgin queens mate when they take their nuptial flight. This is a more or less haphazard method, however, which cannot be absolutely safeguarded. Any method by which desired matings can be brought about with absolute surety may be expected to inaugurate a new period destined to revolutionize bee-breeding. During the past year the Station has been coöperating with Mr. Arthur C. Miller of Providence, an enthusiastic and expert bee-keeper, in experiments along this line. While definite positive results have not yet been obtained, much progress has been made in a direction which lends encouragement to further effort. Mr. Miller's report of what has so far been accomplished is published at this time.

Investigation of Ropy Milk.

During the spring of this year complaint was received from a woman in the northern part of the State, that the milk which she

set in pans, for the cream to rise, became ropy or stringy. She sent a sample of the milk to the Station, and it took but a brief time to determine that the trouble was of bacterial origin. The task of discovering when and how the infection got into the milk was, however, a more difficult undertaking. This has, nevertheless, been accomplished, and it is proposed to treat of the subject of ropy milk in a special bulletin at no distant date.

MISCELLANEOUS.

In addition to the definite lines of investigation which have been mentioned, certain other matters of more or less incidental character have been undertaken.

Mr. Kirkpatrick has tried, upon eggs which were being hatched for certain experiments on feeding, the advantage, if any, in percentage of hatch of turning the eggs a greater or less number of times each day. Half of the eggs were turned twice a day, the other half five times a day. This was tried with a total of 1,886 eggs. Another experiment in which 1,040 eggs were used was designed to test the effect upon the hatch of dipping the eggs in luke warm water upon the nineteenth day of incubation. The results of these experiments will be published later.

During the past two seasons some attempt has been made to produce crosses between the turkey and the common fowl, the guinea-fowl and the common fowl, and a ring-necked pheasant cock and a bantam hen. Only the last had a successful issue, and in this case only one out of 26 eggs incubated was fertile. From the one fertile egg hatched a most curious hybrid, which it is proposed to describe when it has attained its adult plumage.

The Rhode Island Station is gradually coming to be regarded as an authority on poultry diseases, and persons making inquiries are often directed here by the officers of the Stations of other States. The Division has at all times, as previously, held itself ready to aid the poultrymen of the State in any way in its power, and help and ad-

vice have also been given to persons outside the State in so far as was practicable.

During the winter months, when the plant was not being utilized for experiments in connection with pathological or breeding work, its facilities were largely turned over to another Division for use in experiments on the feeding of chicks for broiler purposes. Considerable of the time of several assistants of the Division was also devoted to this work.

Comparatively little has been done in the way of building during the past year. The "squab house" (see map in report of last year) was moved to the east side of the pigeon house and connected with an opening into the latter. It is now used for housing the "Inside" or "Parlor" Tumblers. Serious leaks made a new front and roof to the brooder house a necessity. Furthermore, a brick chimney was constructed in the same building to replace the pipe which had formerly been used, and which was constantly causing trouble and having to be renewed. The general improvements of the grounds have been continued. Additions to the cinder roadway and the conversion of the plat north of the cottage into a lawn have greatly improved the appearance of the place.

The assistants and laborers in the Division remained nearly as the year before, with the exception of Mr. W. F. Schoppe, who, though nominally in this Division, devoted the major portion of his time to the feeding-experiments. Great credit should be given to Mr. Kirkpatrick, who has virtual superintendence of the poultry plant, and who took almost complete charge of matters during the winter.

It is not without sincere regret in many ways that at the end of the year for which this report is being made the present Chief of the Division resigns his position to take up university work. During his tenure of the office his work has been facilitated and made pleasant by the interest and attention shown him both by his superior and his subordinates. He is succeeded by Dr. Hadley, who, from his training and his familiarity with the work, is peculiarly fitted to take it up and carry it on just where it is being left.

It may not perhaps be out of place to say a word as to the opportunities and needs of the Division at this time. First as to the opportunities, which are very great, especially along the line of poultry diseases. These have in the past been comparatively neglected. A few diseases have been systematically studied, their symptoms recognized and defined, and the causative organisms discovered. But in the majority of cases the diseases are known only through local traditions, the symptoms are confused, and the causes unknown. As has already been stated, the Rhode Island Station has acquired some reputation in the study of animal diseases, and is fairly well equipped for the work. It would thus seem to have a field in which it would do well to push ahead persistently and unremittingly, since it is one which promises rich results of the greatest practical importance. The most urgent need of the Division at the present time is a suitable building for the isolation of birds which are sick or being subjected to experimentation; in other words, a hospital. As matters stand now, when some fowl is received with a disease which is perhaps new or little understood, the investigator hesitates to inoculate the disease into other fowls and thus perpetuate it at the Station for purposes of study, for fear of introducing it into the stock which is being kept for other purposes. It would be a serious loss, for example, if some fatal malady should gain access to the one thousand or more chicks being used in a brooder experiment. When these things are considered, the desirability, and, indeed, the absolute necessity, of a hospital in an isolated location, with suitable yards adjoining for the reception, care, and isolation of sick birds, is self-evident. It is to be hoped that such a building may be provided for the Division in the near future.

MATING EXPERIMENTS WITH BEES.*

ARTHUR C. MILLER.

The belief has long existed among the more thoughtful beekeepers that control of the mating of the drones and queens must be secured before any very marked progress in the development and fixing of desirable traits will be possible. Mating takes place while the insects are flying. When the drones (males) and queens (females) are confined either to the hive or to larger enclosures they as a rule fail to mate. But few exceptions are known to this, and not all of the reported exceptions are beyond the possibility of error. Among those generally accepted as authentic are the experiences of Mr. H. L. Jeffrey, of Woodbury, Conn.; J. E. Davitte, of Aragon, Ga.; and W. E. Flower, of Ashbourne, Penn. The first-named had confined in several hives of bees some virgin queens and drones of selected stock. These hives had above the combs a space three to four inches high, free and clear, to give the bees room in which to gather when being moved, it being Mr. Jeffrey's intention to take them some distance from other bees and there liberate them, trusting that the matings of the queens would be with the selected drones.

The hives were moved by wheelbarrow, and on inspection at the end of the journey he found that all of the queens (six?) had mated. Mr. Jeffrey made many subsequent attempts to secure like results,

*The experiments here reported were conducted in coöperation with the Rhode Island Agricultural Experiment Station, and were under the immediate direction of Dr. Leon J. Cole, Chief of the Division of Animal Breeding and Pathology.

but without success. No record exists of any other matings in so small a space. Some persons have expressed the opinion that the queens were mated before being transported, but Mr. Jeffrey is credited with being a careful observer, and, after some inquiry, I believe his statement worthy of record.

Enclosures for mating purposes have been experimented with, and have varied in size from an ordinary jelly tumbler to cages thirty feet high and of the same diameter; also experiments have been made in long greenhouses.

In the smaller enclosures the insects constantly strove to escape, but in the large ones they flew freely. The experiments giving the most promising results were those of Mr. J. F. Davitte, of Aragon, Ga.* He built an octagonal cage thirty feet high and of the same diameter. The framing was of scantling, braced with wires, and covered with cotton mosquito netting. Hives containing bees with drones and queens were placed about the outside of the cage, the hives having two openings, one permitting the escape of drones and queens into the cage, and the other giving the workers freedom to the fields. By keeping the entrance to the cage closed until the worker bees had become accustomed to using the other exit from the hive, but few of them found their way into the cage when access was given to it. Mr. Davitte reported the mating of one hundred queens in this cage.

Mr. Flower's cage was scarcely half the size of that used by Mr. Davitte. His experiments extended over only one season, and he had one queen mated in the cage. Nothing more has been heard from him regarding the problem.

A year or two later the experiments of Mr. Davitte were repeated by another man, but wire cloth was used instead of mosquito netting, and the drones, queens, and workers battered themselves to death by flying against it. This cage was wrecked by a wind-storm soon after its construction, and was not rebuilt.

*See Bee Keepers' Review, February, 1901.

In 1899 the writer began experiments on the flight of bees in various enclosures. White cotton cloth proved to be best, the bees only flying against the side showing the strongest light. Later it was found that they apparently saw through the cloth and tried to pass.*

On making a cage of double walls of cloth, the two walls being about one inch apart, the bees made no further attempts to pass through, but flew normally, as in the open air.

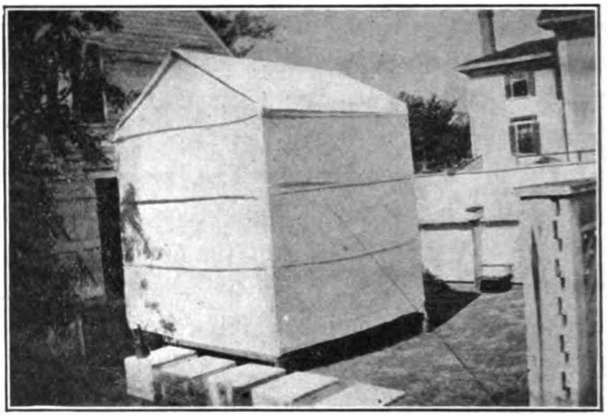

FIG. 1.—Cloth flying cage used in Mr. Miller's experiments on controlling the mating of bees.

In the late summer of 1907, aided by the coöperation of the Director of the Rhode Island Experiment Station, I erected a cloth house nine feet square and nine feet high, with a peaked outer roof, but with a horizontal inner ceiling of cotton cloth. Figure 1 shows a view of this house as it appeared shortly after it was put up. The house was floored, the floor being also covered with white cloth.

*It was not a turning towards the light, but apparently an attempt to fly over trees, etc., which formed an indistinct horizon; for by placing one's self close to the hive and watching the line taken by the bees, it was seen to strike just above the horizon. The sight of the bees appears to be imperfect, and its peculiarities offer to scientists an interesting field for study. [It is not altogether apparent, nevertheless, that this may not have been a direct response to a light area. L. J. C.]

Several small colonies of bees were placed in this house, and observations begun. The workers flew freely about in the cage, and when honey was exposed they gathered it up and took it each to her respective hive. Drones and queens also flew freely, but no success was met with in regard to their mating. This was, at the time, attributed to the lateness of the season, and possibly to the condition of the drones. The drones obtain practically all of their nourishment from the workers, rarely taking honey from the comb. They never gather any nectar from the flowers, and hence, when the workers fail to feed them, they become weak and sluggish and soon perish.

In the spring of 1908 the cage was rebuilt and the experiments were resumed. A strong colony of bees was placed in it, the drones being confined to the cage, while the workers had the freedom of the open. In this manner an abundance of vigorous males was secured. Some workers found their way into the cage and would cluster in the upper corners. Openings were therefore made, and covered with perforated metal, which permitted the passage of the workers, but not of the queens or drones, and freedom from the troublesome clusters was secured. It was found that the virgin queens would often join such clusters, and when two or more were present, fighting took place until but one was left. With the clusters disposed of, there was no further loss of queens; each queen flew freely and returned to her respective hive. Their flight appeared to be normal, since they rose in spirals and kept clear of the walls; but they would often hit against the top. In the open they rise to a great height, but do not go very far from home. The drones, on the contrary, range long distances and fly high.

In the cage the drones did not strike the top, as did the queens, but darted about as when free.

In raising queens from many different strains it was found that they varied greatly in the age at which they mated, and pains were taken to have queens of the different strains in the cage. Drones of one strain seemed to be particularly successful in finding queens

in the open. The strain in question was peculiarly marked, and so, whenever a queen had mated with a drone of that strain, it was readily known by her offspring. This led to the use of drones of various strains in the cage.

Every factor which could be thought of has been embodied in the experiments, but so far without success in the particular matter desired.

Just what the enclosure has to do with the mating of the queen and the drone is a puzzle. The drones were virile, and the queens passed through the various stages of development until they began laying unfertilized eggs. After they reach that period they have never been known to mate. The diameter of the cage seems to have been sufficient for normal flight, but the height may not have been sufficient, and may have had something to do with it.

After the many failures under the most promising conditions, the life history and habits of the bee were again given careful consideration to see if any point which would help could be found. The double-walled cloth cage had overcome the trouble with the bees seeing out. The drones were properly nourished, and were virile. The queens reached the rutting period and flew actively; but the drones paid no attention to them. Obviously something was wrong. The question arose, "How do the males find the females?" Very obviously it is not by scent, for the males never take any notice of the presence of a virgin or fertile queen, nor in any way indicate that she has any odor attractive to them. This is in marked contrast with what we know of moths.

That sight is not the primary means of finding or attraction seems evident. The only remaining possibility seems to be in sound, the means by which some other lace-winged insects find their mates.

On going over all the recorded cage experiments and our own, it was found that in every instance myriads of workers were on the wing all about, and some within, the enclosures; and it seemed quite probable that the roar thus produced would make it impossible for the

drones to distinguish or locate the sound of the flying queen* Is it not possible that the instinct of the queen and drones to fly high has to do with the getting away from the noise of the horde of workers ?†

The question suggests a possible clue to the solution.

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*See Bee Keepers' Review, February, 1901.

†[There may be two reasons why successful matings were not obtained. First, there may have been, as Mr. Miller suggests, failure of the drones to find and recognise the queen, and, second, it may be that even though the queen was found, and recognised, mating did not occur because of the unfavorable conditions, *i. e.*, the confinement, and especially the limitation of vertical space. The act of mating may perhaps depend upon some responsive reaction of the female when she is approached, and this reaction may not be given by the queen unless she has room for vertical flight. Mr. Miller states that whereas the drones flew freely in the cage, the females often went to the roof. Mating dependent upon the reaction of the female has been observed in the amphipods (beach fleas). The males grasp indiscriminately any individuals with which they come in contact, but retain their hold only upon those which do not struggle to get away, *i. e.*, the unfertilized females. L. J. C.]

THE CROW AS A MENACE TO POULTRY RAISING.

LEON J. COLE.

That the common crow (*Corvus brachyrhynchos*) is a not infrequent despoiler of the nests of other birds has long been known, while his attacks upon poultry and eggs were among the grievances held against him by the early settlers. It is perhaps, not generally appreciated that the crow is distinctly omnivorous, and that under natural conditions a large proportion of its food consists of animal matter. According to Borrows and Schwarz,* roughly speaking, one-third of the food of crows consists of animal matter; during certain months, especially April and May, the proportion of animal food consumed is nearly double, while in the fall and winter it is correspondingly less.

The crow's depredations upon poultry consist almost entirely in the destruction of eggs and the killing of the young. Adult fowls are probably seldom attacked unless sick and weakened. The eggs of the turkey, which is commonly allowed to roam and select its nesting site far removed from the house or poultry yard, are especially liable to destruction by crows. They do frequently, however, attack chicks, young turkeys and even goslings. Interesting accounts of the methods employed by the crows to evade the vigilant care of the parents, are given in the bulletin of which mention has just been made (see section on "Destruction of eggs and young of poultry," pp. 37-40.) It is reported that crows sometimes attack even such large animals as sheep and swine.

Serious depredations of crows upon poultry and eggs appear to

* Barrows, Walter B., and E. A. Schwarz. "The common crow of the United States." U. S. Dept. Agric., Div. Ornith. and Mam., Bull. No. 6, 98 pp. Washington, 1895.

occur only in certain localities, while in other places, though the crow may have an unsavory reputation, as he generally does in farming communities, he is at least free of this opprobrium. The reasons for this are probably twofold, depending, first, upon the abundance of other food, and, in the second place, upon the accessibility of poultry. As poultry raising is now generally conducted, when any special attention is given to it, the eggs are no longer exposed to the danger from crows, since the hens lay in regularly appointed houses. Furthermore, the young chicks are, as a rule, much better protected, being confined in yards and runs near the house instead of being allowed to roam at large with their mothers. Nevertheless, as will be illustrated below, the crows may become very daring in their attacks when other food is scarce. The necessity of an abundant supply of food is especially great during the months of April and May, when the crows are rearing their young. Certain experiments on feeding young crows in captivity, which are reported by Forbush* (pp. 45-50), indicate that the young crows require a large proportion of animal food, and that, when fledged, they "absolutely require a daily amount of food equal to about one-half their own weight; and it is evident that they will consume much more than this to their own advantage if they can get it." Since young chicks are usually raised at about the same time it is evident why they often furnish a very acceptable addition to the crow's larder.

Judging from the fact that comparatively few complaints have been received, it would appear that the poultry raisers of this State have not been greatly troubled by the crow. During the past season, however, two cases have been reported from different sections of the State, in which the depredations by the crows have been so persistent as to cause serious losses. The first of these was reported by Dr. V. L. Leighton, who has an extensive poultry plant not more

* Forbush. Edward Howe. "Useful birds and their protection." Published under direction of the Massachussetts State Board of Agriculture, second edition, 1907, xx + 437 pp., 56 plates, colored frontispiece and many figures.

than a half-mile from the Experiment Station in Kingston. Dr. Leighton's plant is not a great way from a large piece of woodland in which crows are abundant. His experience this year was as follows:

He was troubled most seriously from about April 1 to July 10. This is just the season during which the crows are raising their young and the young are learning to forage for themselves. Dr. Leighton estimates that during this period he lost, from the depredations of the crows alone, in the neighborhood of 100 chickens, which was about 25 per cent of those hatched and not lost from other causes. All sizes were taken, from the time they were just hatched until they were a pound in weight. The larger chicks the crows killed and ate where they caught them, but the smaller ones they carried away in their beaks. Various efforts were made to keep the crows away, most of which were ineffectual. The first was a scarecrow, but this had little or no effect. In the second place corn soaked in strychnin solution was scattered on a field of planted corn at a little distance from the chicken yard. This may have killed some crows, but no dead ones were found. No corn was pulled, but there was no appreciable decrease in the number of chickens taken. Third, a steel trap was set on a pole near the chicken yard, but without success. Fourth, white twine was run on stakes around and across the chicken yard; this kept the crows from the yard, but the small chicks would get out, and would then still fall a prey to the crows. Finally, a crow was shot and hung on a pole near the chicken yard, after which there was no further trouble. It is Dr. Leighton's opinion that stealing chickens is a common habit of crows in this State. He has been troubled before, but never so seriously.

The other instance of serious losses this season, to which reference has already been made, occurred near Cumberland Hill, in the northern part of the State. This was on the farm of Mr. E. E. Church, who was attempting to raise ducks on a suitable pond not a great distance from his house. The first lot hatched consisted of

135 ducklings; later in the season there remained of these but fourteen. In a later lot he had 70 ducklings, and saved only thirteen of them. The loss of nearly 87 per cent he attributes almost wholly to crows. Mr. Church thought the crows carried the ducklings away in their claws, but in this he was probably mistaken. Mr. Church also found a scarecrow ineffectual in keeping the crows away.

The question of whether the crow is on the whole beneficial to agricultural interests, or whether he does more harm than good, is one that will probably have to receive a different answer in accordance with different conditions. That he does a great deal of good at times by the destruction of noxious insects cannot be denied, though it would probably be difficult to convince the average farmer that he is anything but a thief and a rascal. The problem is in reality an extremely complex one, depending upon a great many variable factors, especially the absolute and relative abundance of various kinds of food. When other food is scarce the crow turns to poultry, but when certain insects, (such, for example, as the beetles commonly known as "June bugs") are abundant, the crow feeds largely upon them. Forbush, in the work mentioned above, devotes several pages (pp. 8-11) to a discussion of the possible inter-relations of the crow and certain other birds, on the one hand to injurious insects, and on the other to insects and birds which are useful to agriculture. But whatever may be the crow's good points in particular cases, it is not likely that the poultry man who is suffering serious losses by his depredations will be inclined to look upon him with favor. For this reason it is probably well that the State does not offer the crow protection; but that it is wise to give a bounty on all crows killed is not so certain. The matter is one which would probably be more or less locally self-adjusting without the bounty, for in those localities where crows are proving harmful this should in itself act as an incentive for lessening their numbers, while if they are doing no harm or are perhaps of benefit in other places, a bounty will work against its own ultimate ends, namely, the interests

of the agriculturist. It happens, however, that the crow is a bird fully capable of looking out for himself under all ordinary conditions, and as Forbush says (*loc. cit.*, p. 406): "Our laws which deny protection to the crow are wise, for it is one of those species which, though at times most useful, may become a pest if not held severely in check."

It should perhaps be mentioned that it is the opinion of many observers that the egg and poultry stealing habit is not common to all of the crows of even a single locality, but that the habit is acquired by certain individuals only, and that if these can be shot the trouble will be stopped.

METHODS OF KEEPING PEDIGREE RECORDS IN USE AT THE RHODE ISLAND AGRICULTURAL EXPERIMENT STATION.

LEON J. COLE.

As written language is a conventional scheme which greatly facilitates the recording and orderly arrangement of ideas, just so some definite scheme of records is of great importance in putting in accurate, permanent and accessible form the results of scientific investigation. The primary requisite of such a scheme is that the records shall be accurate and clearly understandable, that is, not ambiguous. Next they should be in such a form that the data desired can be obtained from them with the least possible trouble. In other words, even though the records do not, as put down, have the desired order, they must be cross-referenced or indexed in such a way that the correlated facts may readily be assembled. This is accessibility. Finally, a great desirability is simplicity. This not only saves much time in the recording of the data, but conduces to clearness and thus saves time also in the utilization of the records.

At the time the writer came to the Rhode Island Experiment Station in September, 1906, it was desired that certain investigations in the breeding of poultry, especially turkeys, should be undertaken. It was therefore necessary that some scheme of records should be decided upon and adopted. After the methods employed by some of the foremost investigators in scientific breeding in this country had been examined, a scheme was finally adopted which differs considerably from any in use at that time, so far as the writer is aware, but based upon certain suggestions put forward by Galton* a few years earlier. Galton's suggestions were for the keeping of

* Galton, Francis. Pedigrees. Nature, Vol. 67, No. 1747, pp. 586, 587, 1903.

human pedigree records, and a considerable modification of his scheme was necessary in order to adapt it to animals. The general plan is one, however, which lends itself readily to modification and adaptation to special uses, and not only is it usually necessary or advisable to make certain changes, according to the kind of animal studied, but also according to the purpose of the particular investigation and the needs of special cases. At this Station the plan was first devised for keeping the pedigrees of turkeys, but was later adapted to other poultry, and especially to pigeons. Any serious attempt at an investigation of heredity in turkeys was soon given up because of the study of the blackhead disease of turkeys, which was being made at the same time. This study required the greater number of the young turkeys hatched for inoculation and similar experiments, and so few survived that no quantitative results of the breeding could be obtained. On this account it was necessary to pursue the breeding investigations on another form, and for this the pigeon was chosen. The purpose and scope of the pigeon-breeding investigations will not be discussed at this time; it is the object of the present paper only to describe the methods of recording employed. It may thus serve as a preliminary to the scientific results of the investigation, which will be published later.

Although the descriptive portion which follows will refer specifically to the methods now employed with the pigeon records, some reference will also be made to the general plan as adapted at this Station to turkeys and other poultry. This has, in the two years which it has been in use, given such satisfaction that the original plan is still followed in the case of the turkeys merely as a catalogue of stock, since it has the advantage of keeping the pedigrees as well. A further modification of the same general scheme has been adopted by the biologists of the Maine Station in the pedigree poultry breeding being carried on there. Their special methods are described in a recent bulletin of the Station.*

* Pearl, R., and F. M. Surface. Appliances and methods for pedigree poultry breeding. Maine Agric. Exper. Sta., Bull. No. 159, pp. 239–274, July, 1908.

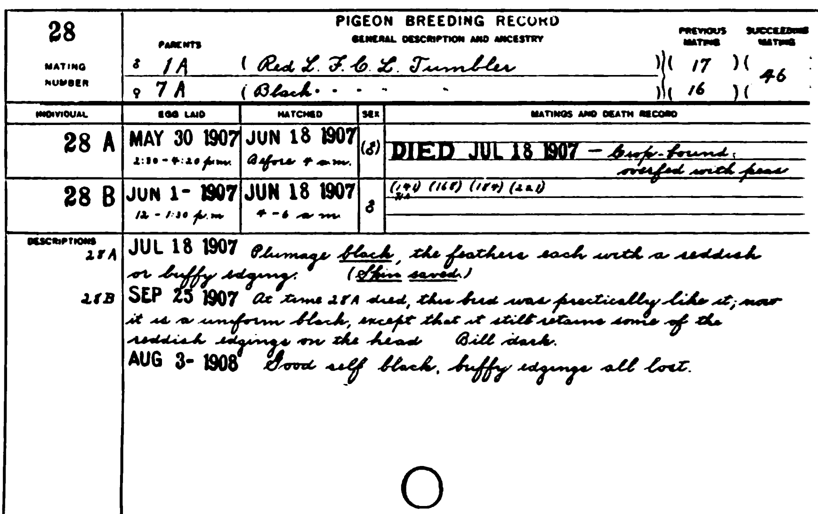
Perhaps the most common method of recording and referring to individuals in pedigree breeding is by means of serial numbers, which are usually given in the order in which the individuals are born (or hatched, as the case may be), irrespective of parentage. Galton's plan for keeping human pedigrees, referred to above, differed from this in one important essential. Instead of giving the serial number to the individual as a unit, he applies the same number to a whole family group. The individual children of this family can then be distinguished by their Christian names. We can use the example given by Galton for illustration. John Gore marries Amy Myers and they have six children: Fred, George, Ellen, Susan, Stephen, and Fanny. These constitute a family group, and to the group, as a whole, is given the lowest unoccupied serial number (in this case 101). Now whenever we meet the number 101 we know it refers to the family of John and Amy Gore. Furthermore when we see, for example, "Ellen Gore 101," we know at once she is one of the children of this particular family group, and there is no danger of confusing her with any other Ellen Gore, since the latter would have the number of some different family group. Also, if we see "Fred Gore 101" and "Fanny Gore 101" we know immediately that they are brother and sister without looking the matter up further.

How this scheme may be applied to animal pedigrees is obvious at once. Instead of a "family group" we now have a mating and the resulting offspring. The serial number is now applied to the mating and may be called a "mating number." But here a difficulty arises, since the different individual offspring must be distinguished, and it is not convenient to give a name to each. The plan has therefore been adopted of applying to the individuals a letter of the alphabet, which is written immediately after the mating numbers, the two together becoming the "name" of any individual.*

* For special reasons this plan has been modified at the Maine Station, so that the individuals do not bear their mating number. The reason for this change is the technical difficulty of banding a large number of chicks at one time, it being much simpler to put on bands bearing consecutive numbers than to have to select the proper band for each chick. See Bulletin No. 159 of the Maine Station, referred to above.

Thus if the mating were No. 101, the individual offspring would be 101 A, 101B, 101C, etc.* It is to be observed here, again, that the number 101 at once shows all the individuals to be from the same mating. It should also be remembered that *a number not followed by a letter always refers to a mating and never to an individual.*

There is one other datum indicated by the Christian name in the case of the members of a human family group that is not indicated in the system outlined here for animals, and that is the sex. The sex of the individual, therefore, has to be recorded separately. All this can be made more clear by considering a concrete example.


28 MATING NUMBER

PIGEON BREEDING RECORD

GENERAL DESCRIPTION AND ANCESTRY

PARENTS		PREVIOUS MATING	SUCCEEDING MATING
♂ 1A	(Red L. F. C. L. Tumbler	17	46
♀ 7A	(Black " " " "	16	

INDIVIDUAL	EGG LAID	HATCHED	SEX	MATINGS AND DEATH RECORD
28 A	MAY 30 1907 2:30 - 4:20 p.m.	JUN 18 1907 Before 4 a.m.	(♂)	DIED JUL 18 1907 — Crop-found; overfed with peas
28 B	JUN 1- 1907 12 - 1:30 p.m	JUN 18 1907 4 - 6 a m	♂	(141) (168) (184) (221)

DESCRIPTIONS

28A JUL 18 1907 Plumage black, the feathers each with a reddish or buffy edging. (Skin saved.)

28B SEP 25 1907 At time 28A died, this bird was practically like it; now it is a uniform black, except that it still retains some of the reddish edgings on the head Bill dark.

AUG 3- 1908 Good self black, buffy edgings all lost.

Fig. 1.

Figure 1 shows a "mating card"† from the pigeon pedigree records. This is made directly from one of the regular cards and contains the same data as the original. The number 28 in the upper left hand

* In cases where there are more offspring than letters in the alphabet a small numeral is added after the letter; thus the 27th and 28th individuals would be $101A_2$, $101B_2$, etc.

† These records are kept on specially ruled and printed "Library Bureau" cards of the 12.5 cm. × 20 cm. size. Great advantages are claimed at the Maine Station for the "loose leaf system." The plan of records is equally adaptable to either.

corner is the "mating number," and, as has been stated, is one of a continuous series. This number, both here and in the column under "Individual" below, is stamped with an automatic numbering machine, which, though it may not save much time, adds legibility, neatness and accuracy. To the right of the mating number are recorded the individual numbers of the parents, that of the male always being put above the line with the female's number below. To the right in parenthesis is added a brief statement of what each parent is (color and breed), and for convenience a hint as to ancestry may be added to save looking it up. Thus 1A is a red long-faced clean-legged tumbler, whereas the female, 7A, is a black bird of the same breed. It happens that both of these were purchased, so that their ancestry is unknown. Suppose, however, that one of them had been an offspring of the second generation from a cross between a red and a black pigeon; this could have been indicated by adding "F_2, red × black." None of the data included here in the parenthesis are of course necessary on the card, but entering it saves the necessity of referring back to the mating cards of the parents, and shows at a glance what sort of mating is being made. Finally, as regards the parents, the last previous and next succeeding mating of each is added, in order to facilitate running through the cards when it is desired to follow out the matings of a particular bird. Mating 28 shows us that previous to this mating these birds were paired with different mates, since one was in mating 17 and the other in mating 16. After mating 28 they were left together, however, and their next offspring are numbered 46. It would have been possible to retain the same number so long as any two birds remained mated, giving consecutive letters to the offspring, but on account of advantages to be gained in other ways, a new number is given each time the birds lay a complement of eggs. As they lay only two eggs at a time, the young are therefore always A and B (except in a special case to be mentioned later).

Below the double line are recorded the data of the eggs laid and of the young birds from the time they hatch till they die. Thus it is

seen that the first egg (the one destined to produce squab 28A) was laid between 2:30 and 4:20 P. M. on May 30, 1907.* Two days later, on June 1, the second egg was laid between noon and half-past one in the afternoon. In the next column to the right is recorded the fact that squab 28A hatched before 4 A. M., on June 18, and squab 28B hatched sometime between 4 and 6 o'clock on the same morning. In order that it may be known with certainty which squab hatches from egg A, and which from egg B, (the eggs are marked 28A and 28B as laid), shortly before they are due to hatch one of the eggs (B) is taken from the nest and placed in an incubator. After hatching a string is tied loosely around the leg of the squab and it is returned to its nest. When the squabs are about ten days old closed, or "seamless," aluminum bands bearing their number are slipped on over their feet, so that when the birds are old enough to leave the nest the band could not be removed without cutting. The determining of the particular squab which comes from each egg, as well as observing as nearly as possible the times of laying and of hatching, has no bearing on the heredity investigations, but has to do with a different problem which is being investigated at the same time. If one of the eggs were not removed to the incubator both might hatch during an interval between observations, in which case it would be impossible to tell which squab was A and which B. This does sometimes happen, and in such a contingency, the fact is made evident by designating the young as X and Y, instead of A and B.

To return to mating 28, we find that when squab 28A was a month old it died† from being over fed (probably by its parents, though possibly by some "feeder" which had older squabs of its own). There appears to be no way of determining the sexes of pigeons from external characters, and this squab was too young at the time of its death for its sex to be told by its actions. Dissection, however, showed it to be a male, as recorded in the "Sex" column, and the fact that the sign signifying sex is enclosed in parentheses indicates that the sex was determined in this way.

* Dates are stamped in with a rubber dating stamp.

† A rubber stamp is used for recording the death.

Squab 28B lived to be old enough to breed; he has, in fact, bred four times. That this bird was also a male could of course be ascertained at that time. The numbers of the various matings of 28B are given at the right, each enclosed in parentheses, which is the conventional means used of indicating a mating number when it is not at the head of its card. The number 71A below (141) indicates that 28B was mated with the female 71A, and since no other number is given in the succeeding matings, he is still mated to this same female. Here again this record is not essential on this card, but is added only for convenience, since the mate of 28B could be ascertained by turning to card 141 even if it were not given here.

Mating card 141 bears the following data at its top:

141 MATING NUMBER	PARENTS	GENERAL DESCRIPTION AND ANCESTRY	PREVIOUS MATING	SUCCEEDING MATING
	♂ 28 B	(Black L. F. C. L. Tumbler — F_1 red x black)	(—)	(168)
	♀ 71 A	(" " " " " " — F_1 black x red)	(—)	( )

The lower part of this card would have the data for birds 141 A and 141 B in the same way that figure 1 shows the data for 28A and 28B.

Attention has already been called to the fact that the last preceding and next succeeding matings are recorded for each of the parents on all the mating cards. Thus the previous mating of 1A was 17, and of 7A it was 16; the succeeding mating of each is 46. If it is desired to see at once all the matings of either one of these birds it is but necessary to turn to card 1 or 7 as the case may be, where they are all entered.

Turning again to Figure 1, it is seen that the lower half of the card is reserved for descriptions, and here are recorded the characters the inheritance of which are being studied.

This is all there is to the system. There is only one set of numbers and cards; and once the central idea is grasped is will be seen to be exceedingly simple. All essential data are recorded in the most concise way and without the necessity of repetition, repetition being made only in so far as may aid in convenience of cross referencing.

Although there is no necessary consecutive order beyond the numbering of the matings, the automatic cross-referencing which results enables any desired line to be followed out in the shortest space of time and with the least trouble. As the number of matings becomes large, however, it will probably be found that certain indexes can be added to advantage. Thus an index could be made to the birds of diffrent colors or possssing certain other characters. Or there might be an index of the different crosses, after each cross being enumerated the matings in which that cross has been made, e. g.:

black × red, (45) (56) (67) (71) (88) (104) (134) (169) (194) (228)*
red × black, (28) (46) (59) (69) (82) (99) (126) (158) (195) (226).*

If it is desired to put any particular pedigree or part of the same in the ordinary chart form, this can be done in a very short time merely by following back and forth through the cards by means of the numbers, for on every card one finds, on the one hand, the numbers of all the matings of the birds there recorded, while on the other, the data of their parents may be had by turning to the card corresponding to the number of the parents, which is given in their designation at the top of the card in question.

The test of every such system is the way it holds up when it is put into use. The methods here described have now been in practical use at this Station for more than two years, and have proven very satisfactory. It is planned that this account of the scheme may at no distant date be followed by a report on some of the results that have been obtained by its use.

* From actual records.

REPORT OF METEOROLOGIST.

NATHANIEL HELME.

SUMMARY, JULY 1, 1907, TO JUNE 30, 1908.

Temperature, Fahrenheit.

Maximum............	89°	July 18 and 19, 1907; June 20, 1908.
Minimum............	— 4°	January 31, February 8, 1908.
Highest daily mean....	78°	July 18 and 19, 1907.
Lowest daily mean ...	8.5°	February 8, 1908.
Highest monthly mean.	69.7°	July, 1907.
Lowest monthly mean	25.3°	February, 1908.
Mean of the year......	48.5°	

Precipitation. (Rain and melted snow.)

Greatest in any 24 consecutive hours.	3.16 inches, May 7–8, 1908.
Largest monthly total...............	8.03 inches, November, 1907.
Least monthly total................	.72 inch, July, 1907.
Total for the year..................	53.75 inches.
Snowfall (unmelted)................	37 inches.

December, 1907, 13 inches; January, 1908, 8 inches; February, 12.5 inches; March, 3.5 inches.

Prevailing Winds.

The prevailing winds were from the west in every month, excepting July, 1907, and May, 1908, when they were from the southwest.

Weather.

Number of clear days in the year	158
Partly cloudy days	120
Cloudy days	88
With precipitation of .01 inch or more	97

The principal characteristics of the weather for each month were as follows:

The total rainfall for July was the least, for that month, on the Station record of nineteen years. Crops suffered from lack of moisture. The hay crop was secured in good condition.

Dry weather continued during the month of August and although the rainfall was twice as much as that of July, it brought but little relief and at the end of the month water was very low in wells and streams.

The total precipitation for September was the largest for the month since 1899, and greater than that of the three summer months combined. There was killing frost on low land on the 27th.

The mean temperature was the lowest for the month of October since 1895, and the maximum was the lowest for the month during the Station record of nineteen years.

The total precipitation for November was the largest for the month since 1897. A trace of snow, the first of the season, fell on the morning of the 13th. The mean temperature of the month was very near the normal.

The maximum temperature for the month of December was the highest for the month on the Station record, and the mean temperature was the highest since 1891. The total precipitation was three inches above the normal for the month.

The weather for the first three weeks of January was mild and unseasonable, but the low temperatures of the last week brought the mean to very near the normal for the month. The total precipitation was below the normal for the month and was mostly in the form of rain, the ground being bare of snow until the storm of the 24th.

The mean temperature for February was one degree below the average for the month, but was 5° more than that of February 1907. The precipitation was above the average and was the largest for the month since 1903.

The weather for March was mild with absence of the high winds generally experienced during that month. There was no frost in the ground at the end of the month, and both its coming and going were "lamb-like."

The mean temperature of April was slightly above the average for the month. The maximum temperature was the highest for the month since 1893, and the minimum the lowest since 1900.

The May rainfall was above the normal and the largest for the month since 1901. There were a number of heavy rains. The high wind accompanying the rain on the 30th made it one of the worst storms of the month.

Low temperatures were frequent in the first part of the month of June, and there were killing frosts in some places as late as the middle of the month. The sun was visible every day of the month and there was but one day registered as cloudy, it being so at the times of observation, though the sun was shining during the early hours of the day.

WEATHER SUMMARY FOR JULY, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	80°	56°	68.0°	....	S. W.	Clear.
2	73	58	65.5	.06	S. W.	Fair.
3	76	61	68.5	.02	N. W.	Fair.
4	77	52	64.5	....	S. W.	Clear.
5	80	53	66.5	....	S. W.	Clear.
6	79	55	67.0	....	S. W.	Clear.
7	75	58	66.5	....	S.	Cloudy.
8	83	61	72.0	....	S. W.	Fair.
9	85	62	73.5	....	W.	Clear.
10	80	56	68.0	....	W.	Clear.
11	70	59	64.5	.05	N. E.	Cloudy.
12	82	59	70.5	.01	Variable.	Fair.
13	80	55	67.5	....	W.	Clear.
14	82	58	70.0	....	S. W.	Clear.
15	75	59	67.0	....	E.	Fair.
16	77	62	69.5	....	S.	Fair.
17	83	65	74.0	....	S. W.	Fair.
18	89	67	78.0	....	S. W.	Fair.
19	89	67	78.0	....	S. W.	Fair.
20	77	63	70.0	.20	S. W.	Fair.
21	82	59	70.5	....	W.	Clear.
22	83	58	70.5	....	S.	Fair.
23	89	64	76.5	....	N. E.	Fair.
24	76	59	67.5	....	E.	Cloudy.
25	84	61	72.5	....	S. W.	Fair.
26	77	64	70.5	.27	S.	Fair.
27	78	54	66.0	....	W.	Clear.
28	83	55	69.0	....	S. W.	Clear.
29	81	60	70.5	Trace.	S. W.	Fair.
30	78	61	69.5	.11	Variable.	Fair.
31	83	58	70.5	....	W.	Clear.
Sum......	2,486	1,839	2,162.5	.72	....	....
Mean.....	80.2	59.3	69.8	....	....	....

Maximum temperature, 89°; minimum, 52°; mean, 69.8°; clear days, 12; fair, 16; cloudy. 3; prevailing wind, Southwest.

WEATHER SUMMARY FOR AUGUST, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	80°	58°	69.0°	....	S. W.	Fair.
2	80	61	70.5	....	S. W.	Fair.
3	85	61	73.0	....	W.	Clear.
4	72	55	63.5	.44	N. W.	Fair.
5	77	51	64.0	....	S.	Fair.
6	73	61	67.0	.07	S. W.	Fair.
7	85	61	73.0	.05	W.	Clear.
8	85	61	73.0	....	E.	Clear.
9	76	57	66.5	....	S. E.	Fair.
10	81	59	70.0	....	S.	Fair.
11	85	62	73.5	....	S.	Clear.
12	83	64	73.5	....	S. W.	Fair.
13	87	63	75.0	....	W.	Fair.
14	81	56	68.5	....	W.	Clear.
15	78	50	64.0	....	W.	Clear.
16	77	50	63.5	....	S. W.	Clear.
17	70	55	62.5	.05	S. W.	Cloudy.
18	86	62	74.0	....	N. W.	Fair.
19	77	48	62.5	....	W.	Clear.
20	80	50	65.0	....	S. W.	Clear.
21	84	61	72.5	.17	S. W.	Cloudy.
22	77	54	65.5	....	S. E.	Fair.
23	75	51	63.0	....	S. E.	Fair.
24	65	55	60.0	.69	S. E.	Rain and f
25	78	59	68.5	....	W.	Fair.
26	74	51	62.5	....	W.	Clear.
27	74	46	60.0	.02	W.	Fair.
28	75	55	65.0	....	W.	Clear.
29	77	48	62.5	....	W.	Clear.
30	73	48	60.5	Trace.	W.	Cloudy.
31	73	54	63.5	....	N. W.	Clear.
Sum......	2,423	1,727	2,075	1.49	....	....
Mean.....	78.2	55.7	66.9	....	....	....

Maximum temperature, 87°; Minimum, 46°; Mean, 66.9°; Clear days, 13; Fair, Cloudy, 4; Prevailing wind, West.

WEATHER SUMMARY FOR SEPTEMBER, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day
	Max.	Min.	Mean.			
1	69°	49°	59.0°	....	N. W.	Fair.
2	65	48	56.5	.53	S.	Rainy.
3	73	60	66.5	.43	S. E.	Rainy.
4	75	64	69.5	2.53	S.	Rainy.
5	73	65	69.0	.35	S.	Cloudy and rain.
6	78	60	69.0	....	W.	Fair.
7	76	53	64.5	....	S. W.	Clear.
8	70	57	63.5	Trace.	S.	Cloudy.
9	70	59	64.5	....	N. E.	Cloudy.
10	72	59	65.5	....	N. E.	Cloudy.
11	75	61	68.0	.26	S. E.	Cloudy and rain.
12	75	58	66.5	....	W.	Clear.
13	78	54	66.0	....	S.	Clear.
14	78	56	67.0	....	Variable.	Clear.
15	79	58	68.5	....	W.	Clear.
16	84	62	73.0	....	S. W.	Fair.
17	83	63	73.0	....	S. W.	Fair.
18	65	50	57.5	....	N. E.	Cloudy.
19	60	47	53.5	....	N. E.	Cloudy.
20	67	52	59.5	....	S.	Cloudy.
21	83	63	73.0	....	S. W.	Fair.
22	76	62	69.0	Trace.	S. W.	Cloudy.
23	72	54	63.0	.81	S. W.	Cloudy and rain.
24	75	60	67.5	.17	S. W.	Fair.
25	65	46	55.5	....	N. W.	Clear.
26	60	38	49.0	....	W.	Clear.
27	62	36	49.0	....	W.	Fair.
28	68	51	59.5	Trace.	N. E.	Cloudy.
29	57	44	50.5	1.81	N. E.	Rainy.
30	57	40	48.5	....	S. W.	Fair.
Sum......	2,140	1,629	1,884.5	6.89	....	....
Mean.....	71.3	54.3	62.8	....	....	....

Maximum temperature, 84°; Minimum, 36°; Mean, 62.8°; Clear days, 7; Fair, 8; Cloudy, 15; Prevailing wind, West.

WEATHER SUMMARY FOR OCTOBER, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	59°	38°	48.5°	....	N. W.	Clear.
2	62	35	48.5	....	N. W.	Clear.
3	67	42	54.5	....	S. W.	Clear.
4	65	57	61.0	.57	S. W.	Rainy.
5	65	46	55.5	....	W.	Clear.
6	60	35	47.5	....	W.	Clear.
7	67	44	55.5	....	S.	Clear.
8	65	38	51.5	1.25	W.	Fair.
9	55	29	42.0	....	S. E.	Clear.
10	57	35	46.0	....	S.	Fair.
11	62	40	51.0	....	S. E.	Clear.
12	62	43	52.5	....	W.	Fair.
13	60	38	49.0	....	N.	Clear.
14	60	37	48.5	....	N. E.	Fair.
15	59	37	48.0	....	W.	Clear.
16	64	35	49.5	....	W.	Clear.
17	67	40	53.5	....	S. W.	Clear.
18	68	43	55.5	....	W.	Clear.
19	52	29	40.5	....	W.	Clear.
20	51	32	41.5	.11	S.	Cloudy and
21	45	29	37.0	....	W.	Clear.
22	56	26	41.0	....	W.	Clear.
23	63	39	51.0	....	S. W.	Clear.
24	50	32	41.0	....	W.	Clear.
25	58	25	41.5	....	S. W.	Fair.
26	50	30	40.0	....	W.	Clear.
27	54	30	42.0	....	S. E.	Cloudy.
28	60	53	56.5	.68	S. E.	Cloudy and
29	55	37	46.0	.45	N. W.	Clear.
30	47	29	38.0	....	W.	Clear.
31	51	24	37.5	....	N. E.	Clear.
Sum......	1,816	1,127	1,471.5	3.06	....	....
Mean.....	58.6	36.4	47.5	....	....	....

Maximum temperature, 68°; Minimum, 24°; Mean, 47.5°; Clear days, 22; Fai
Cloudy, 4; Prevailing wind, West.

WEATHER SUMMARY FOR NOVEMBER, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	53°	30°	41.5°	....	W.	Fair.
2	55	37	46.0	.24	N. E.	Rainy.
3	60	47	53.5	.45	W.	Clear.
4	50	34	42.0	....	W.	Clear.
5	55	25	40.0	....	S. E.	Clear.
6	55	40	47.5	2.44	N. E.	Rainy.
7	56	43	49.5	....	W.	Cloudy.
8	54	39	46.5	....	W.	Fair.
9	60	41	50.5	....	S. W.	Fair.
10	56	47	51.5	.12	S.	Rainy.
11	54	34	44.0	....	N. W.	Fair.
12	40	26	33.0	....	W.	Cloudy.
13	42	27	34.5	.03	N. W.	Fair.
14	40	24	32.0	....	W.	Clear.
15	42	21	31.5	....	W.	Clear.
16	45	27	36.0	....	N. E.	Clear.
17	47	28	37.5	....	W.	Clear.
18	47	29	38.0	.05	W.	Cloudy.
19	47	36	41.5	.54	N.	Fair.
20	40	30	35.0	....	N.	Fair.
21	48	27	37.5	.19	N. E.	Cloudy and rain.
22	55	48	51.5	.31	N.	Cloudy.
23	53	42	47.5	....	N. E.	Cloudy.
24	42	37	39.5	.88	N. E.	Rainy.
25	45	36	40.5	2.71	N. W.	Rain and fair.
26	40	28	34.0	.07	W.	Fair.
27	43	30	36.5	....	W.	Clear.
28	53	28	40.5	....	W.	Fair.
29	43	30	36.5	....	W.	Fair.
30	40	25	32.5	....	N.	Clear.
Sum......	1,460	996	1,228	8.03	....	....
Mean.....	48.7	33.2	40.9	....	....	....

Maximum temperature, 60°; Minimum, 25°; Mean, 40.9°; Clear days, 9; Fair, 11; Cloudy, 10; Prevailing wind, West.

WEATHER SUMMARY FOR DECEMBER, 1907.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Charact of Day
	Max.	Min.	Mean.			
1	30°	23°	26.5°	....	N. E.	Cloudy
2	32	18	25.0	.05	W.	Fair.
3	36	16	26.0	....	S. W.	Fair.
4	28	23	25.5	.57	N.	Cloudy and
5	30	19	24.5	....	N. W.	Fair.
6	34	14	24.0	....	W.	Fair.
7	46	22	34.0	....	S. W.	Clear.
8	51	25	38.0	....	S. W.	Clear.
9	55	33	44.0	....	S. W.	Fair.
10	55	44	49.5	1.66	S.	Rainy
11	52	32	42.0	....	W.	Cloudy
12	35	25	30.0	....	W.	Clear.
13	36	18	27.0	....	W.	Clear
14	33	25	29.0	.93	N. E.	Snow and
15	37	30	33.5	.06	N. E.	Cloudy
16	35	26	30.5	....	W.	Cloudy
17	38	25	31.5	....	W.	Clear
18	40	22	31.0	....	W.	Fair.
19	36	20	28.0	....	W.	Clear
20	36	20	28.0	....	S. W.	Fair.
21	40	24	32.0	....	W.	Clear
22	44	21	32.5	....	S. W.	Clear
23	55	32	43.5	2.45	S.	Rainy
24	50	32	41.0	....	W.	Clear
25	42	26	34.0	....	S. W.	Fair.
26	47	29	38.0	....	W.	Clear
27	52	28	40.0	....	Variable.	Clear
28	53	39	46.0	....	S. W.	Fair
29	47	29	38.0	....	N. E.	Fair
30	54	29	41.5	2.27	S.	Rainy
31	47	32	39.5	....	W.	Clear
Sum.....	1,306	801	1,053.5	7.99	....	....
Mean.....	42.1	25.8	34.	....	....	....

Maximum temperature, 55°; Minimum, 14°; Mean, 34°; Clear days, 12; Fair, 10; 9: Prevailing wind, West.

WEATHER SUMMARY FOR JANUARY, 1908.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	45°	30°	37.5°	....	W.	Clear.
2	38	25	31.5	....	W.	Clear.
3	35	21	28.0	....	N. W.	Clear.
4	38	15	26.5	.28	S.	Rainy.
5	40	12	26.0	....	W.	Clear.
6	33	7	20.0	....	W.	Clear.
7	51	20	35.5	1.00	Variable.	Rainy.
8	52	32	42.0	....	W.	Fair.
9	38	23	30.5	....	W.	Cloudy.
10	30	15	22.5	....	W.	Clear.
11	40	16	28.0	....	Variable.	Clear.
12	50	30	40.0	.72	S. E.	Rainy.
13	48	35	41.5	....	S. W.	Cloudy.
14	36	21	28.5	....	W.	Clear.
15	36	17	26.5	....	W.	Clear.
16	42	26	34.0	.16	S. W.	Fair.
17	32	14	23.0	....	S. W.	Clear.
18	37	27	32.0	....	W.	Fair.
19	38	16	27.0	....	W.	Clear.
20	41	9	25.0	....	Variable.	Fair.
21	52	31	41.5	....	S. W.	Fair.
22	53	36	44.5	....	S. W.	Fair.
23	36	25	30.5	....	N. E.	Fair.
24	30	15	22.5	.80	N. E.	Cloudy and snow.
25	28	10	19.0	....	W.	Clear.
26	41	18	29.5	....	S. W.	Fair.
27	48	22	35.0	.40	S. W.	Fair.
28	35	13	24.0	....	S. W.	Clear.
29	38	22	30.0	.25	W.	Rain and snow.
30	22	—2	10.0	....	W.	Clear.
31	20	—4	8.0	....	W.	Clear.
Sum......	1,203	597	900	3.61	....	....
Mean.....	38.8	19.3	29	....	....	....

Maximum temperature, 53° ; Minimum, —4° ; Mean, 29° ; Clear days, 15 ; Fair, 9 ; Cloudy 7 ; Prevailing wind, West.

WEATHER SUMMARY FOR FEBRUARY, 1908.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Characte[r] of Day.
	Max.	Min.	Mean.			
1	48°	10°	29.0°	.87	S. E.	Rainy.
2	34	13	23.5	....	W.	Clear.
3	27	9	18.0	....	W.	Clear.
4	20	0	10.0	....	W.	Clear.
5	22	—4	9.0	Trace.	E.	Fair.
6	42	21	31.5	.83	S. W.	Rain and [...]
7	31	15	23.0	....	W.	Clear.
8	15	2	8.5	....	W.	Clear.
9	20	—3	8.5	....	W.	Clear.
10	31	4	17.5	....	S. W.	Clear.
11	45	18	31.5	....	Variable.	Clear.
12	34	18	26.0	....	N. E.	Clear.
13	37	23	30.0	.30	S. E.	Rain.
14	46	36	41.0	....	W.	Cloudy.
15	52	38	45.0	.33	S.	Cloudy.
16	42	28	35.0	....	W.	Clear.
17	36	24	30.0	....	S. W.	Fair.
18	28	15	21.5	....	W.	Clear.
19	45	18	31.5	2.18	N. E.	Snow and [...]
20	40	23	31.5	....	W.	Fair.
21	34	15	24.5	....	S. W.	Fair.
22	36	21	28.5	....	W.	Clear.
23	28	10	19.0	.42	S.	Fair.
24	30	14	22.0	....	N.	Clear.
25	35	10	22.5	....	N. E.	Fair.
26	37	26	31.5	.73	E.	Rainy.
27	38	34	36.0	....	N. W.	Cloudy.
28	35	19	27.0	....	W.	Clear.
29	30	15	22.5	....	W.	Clear.
Sum......	998	472	735	5.66	....	....
Mean.....	34.4	16.3	25.3	....	....	....

Maximum temperature, 52°; Minimum, —4°; Mean, 25.3°; Clear days, 15; Fai[r] [...]
Cloudy, 8; Prevailing wind, West.

WEATHER SUMMARY FOR MARCH, 1908.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	32°	12°	22.0°	.50	E.	Snow and rain.
2	38	28	33.0	.73	E.	Rainy.
3	38	27	32.5	....	N. W.	Fair.
4	36	20	28.0	....	N. W.	Clear.
5	37	18	27.5	....	W.	Clear.
6	35	22	28.5	.49	E.	Snow and rain.
7	48	32	40.0	....	W.	Fair.
8	45	25	35.0	.12	S. W.	Fair.
9	40	27	33.5	.15	W.	Fair.
10	30	14	22.0	....	W.	Clear.
11	52	20	36.0	....	S. W.	Fair.
12	59	33	46.0	....	W.	Clear.
13	46	31	38.5	....	S. E.	Fair.
14	60	39	49.5	.05	Variable.	Clear.
15	52	35	43.5	.35	S.	Cloudy.
16	50	28	39.0	....	W.	Clear.
17	33	18	25.5	.15	Variable.	Snow and rain.
18	35	27	31.0	.45	N. E.	Rainy.
19	47	29	38.0	.52	N. W.	Fair.
20	37	24	30.5	....	W.	Fair.
21	40	17	28.5	....	W.	Clear.
22	45	25	35.0	....	S. W.	Fair.
23	46	35	40.5	.50	S. W.	Cloudy.
24	58	42	50.0	....	S. W.	Fair.
25	45	26	35.5	....	W.	Clear.
26	54	28	41.0	....	S.	Fair.
27	66	43	54.5	....	Variable.	Cloudy
28	58	39	48.5	....	S.	Cloudy.
29	50	41	45.5	.32	W.	Fair.
30	50	31	40.5	....	W.	Clear.
31	48	33	40.5	.05	S.	Cloudy.
Sum......	1,410	869	1,139.5	4.38	....	....
Mean.....	45.5	28	36.8	....	....	....

Maximum temperature, 66°; Minimum, 12°; Mean, 36.8°; Clear days, 9; Fair, 12; Cloudy, 10; Prevailing wind, West.

WEATHER SUMMARY FOR APRIL, 1908.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Characte[r] of Day.
	Max.	Min.	Mean.			
1	50°	32°	41.0°	....	N. E.	Clear.
2	55	31	43.0	.32	W.	Fair.
3	39	25	32.0	....	W.	Clear.
4	34	21	27.5	....	W.	Clear.
5	42	19	30.5	.14	S. W.	Fair.
6	64	35	49.5	....	W.	Clear.
7	69	39	54.0	....	S. W.	Fair.
8	55	38	46.5	.68	N. E.	Rainy.
9	53	35	44.0	....	W.	Clear.
10	51	28	39.5	.28	S. W.	Rainy.
11	60	39	49.5	....	W.	Cloudy and f
12	49	26	37.5	....	W.	Clear.
13	58	30	44.0	....	W.	Fair.
14	51	26	38.5	....	Variable.	Clear.
15	51	35	43.0	.40	S. W.	Cloudy and r
16	53	28	40.5	....	N. W.	Clear.
17	46	20	33.0	....	Variable.	Clear.
18	53	32	42.5	.29	S.	Cloudy and ra
19	60	45	52.5	.30	N. W.	Cloudy and ra
20	46	32	39.0	.06	W.	Rain and sno
21	45	25	35.0	....	W.	Clear.
22	58	31	44.5	....	S. W.	Fair.
23	75	45	60.0	....	S. W.	Clear.
24	62	44	53.0	....	N. E.	Clear.
25	52	40	46.0	....	S. E.	Cloudy and fo
26	78	51	64.5	.08	S. W.	Clear.
27	70	48	59.0	....	S.	Cloudy.
28	65	47	56.0	....	S. W.	Cloudy.
29	67	45	56.0	....	S.	Clear.
30	66	44	55.0	.17	E.	Cloudy and ra
Sum......	1,677	1,036	1,356.5	2.72	....	....
Mean.....	55.9	34.5	45.2	....	....	....

Maximum temperature, 78°; Minimum, 19°; Mean, 45.2°; Clear days, 14; Fair, Cloudy, 11; Prevailing wind, West.

WEATHER SUMMARY FOR MAY, 1908.

	Temperature.			Precipitation. (Inches.)	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	55°	42°	48.5°	.43	W.	Fair.
2	58	38	48.0	.10	S. W.	Fair.
3	58	36	47.0	....	S. W.	Clear.
4	60	37	48.5	....	S. W.	Clear.
5	65	39	52.0	....	S.	Clear.
6	55	42	48.5	....	E.	Cloudy.
7	47	39	43.0	2.00	N. E.	Rainy.
8	57	43	50.0	1.22	N. E.	Rainy.
9	63	45	54.0	....	S. W.	Fair.
10	57	40	48.5	....	N. W.	Fair.
11	79	38	58.5	....	W.	Clear.
12	69	53	61.0	....	S. W.	Clear.
13	82	52	67.0	....	W.	Fair.
14	57	46	51.5	....	N. E.	Cloudy.
15	60	43	51.5	....	Variable.	Cloudy.
16	68	44	56.0	....	Variable.	Clear.
17	70	44	57.0	....	W.	Clear.
18	75	52	63.5	....	Variable.	Clear.
19	70	45	57.5	....	E.	Clear.
20	63	50	56.5	.08	E.	Rainy.
21	62	54	58.0	.11	E.	Cloudy.
22	65	55	60.0	.18	E.	Cloudy.
23	72	55	63.5	.90	S. E.	Rain and fog.
24	82	58	70.0	....	S. W.	Clear.
25	72	55	63.5	....	S. E.	Clear.
26	73	52	62.5	....	S. W.	Fair.
27	83	58	70.5	....	S. W.	Fair.
28	67	51	59.0	....	N. E.	Cloudy.
29	73	50	61.5	....	S.	Fair.
30	70	58	64.0	.87	E.	Rainy.
31	80	57	68.5	....	S.	Clear.
Sum......	2,067	1,471	1,769	5.89	....	....
Mean.....	66.7	47.5	57.1	....	....	....

Maximum temperature, 83°; Minimum, 36°; Mean, 57.1°; Clear days, 12; Fair, 8; Cloudy 11; Prevailing wind, Southwest.

WEATHER SUMMARY FOR JUNE, 1908.

	TEMPERATURE.			PRECIPITATION. (Inches.)	PREVAILING WIND.	CHARACTER OF DAY.
	MAX.	MIN.	MEAN.			
1	76°	55°	65.5°	.08	W.	Fair.
2	75	44	59.5	....	W.	Clear.
3	67	42	54.5	....	W.	Clear.
4	76	51	63.5	....	W.	Fair.
5	72	51	61.5	....	N. E.	Clear.
6	65	43	54.0	....	Variable.	Clear.
7	79	44	61.5	....	W.	Clear.
8	83	52	67.5	....	W.	Clear.
9	76	55	65.5	....	S. W.	Clear.
10	79	59	69.0	....	S. W.	Clear.
11	78	57	67.5	.30	Variable.	Cloudy and rai
12	75	55	65.0	....	W.	Clear.
13	80	54	67.0	....	W.	Clear.
14	83	55	69.0	....	S. W.	Clear.
15	76	59	67.5	....	S.	Fair.
16	72	56	64.0	1.63	N. W.	Fair.
17	70	48	59.0	....	Variable.	Clear.
18	72	50	61.0	....	S. E.	Clear.
19	76	46	61.0	....	S. W.	Clear.
20	89	60	74.5	....	W.	Fair.
21	85	63	74.0	....	W.	Clear.
22	82	61	71.5	....	Variable.	Clear.
23	77	60	68.5	.90	S. E.	Fair.
24	84	62	73.0	.40	S.	Fair.
25	81	65	73.0	....	W.	Fair.
26	74	57	65.5	....	N. E.	Clear.
27	76	52	64.0	....	S.	Fair.
28	76	59	67.5	....	S.	Fair.
29	82	61	71.5	....	S. W.	Fair.
30	85	64	74.5	....	S. W.	Clear.
Sum......	2,321	1,640	1980.5	3.31	....	....
Mean.....	77.4	54.7	66.	....	....	....

Maximum temperature, 89°; Minimum, 42°; Mean, 66°; Clear days, 18; Fair, 11; Cloud 1; Prevailing wind, West.

SUMMARY BY MONTHS, 1907–1908.

Months.	Number of Clear Days.	Number of partly cloudy Days.	Number of Cloudy Days.	Number of Days with .01 inch or more of Precipitation.	Total Precipitation (rain and melted snow), inches.	Snowfall, unmelted, inches.	Maximum Temperature.	Minimum Temperature.	Mean Temperature.	Prevailing Wind.
1907.										
July	12	16	3	7	.72	......	89°	52°	69.8°	S. W.
August	13	14	4	7	1.49	......	87°	46°	66.9°	W.
September	7	8	15	8	6.89	......	84°	36°	62.8°	W.
October	22	5	4	5	3.06	......	68°	24°	47.5°	W.
November	9	11	10	12	8.03	......	60°	25°	40.9°	W.
December	12	10	9	7	7.99	13.0	55°	14°	34.0°	W.
1908.										
January	15	9	7	7	3.61	8.0	53°	—4°	29.0°	W.
February	15	6	8	7	5.66	12.5	52°	—4°	25.3°	W.
March	9	12	10	13	4.38	3.5	66°	12°	36.8°	W.
April	14	5	11	10	2.72	......	78°	19°	45.2°	W.
May	12	8	11	9	5.89	......	83°	36°	57.1°	S. W.
June	18	11	1	5	3.31	......	89°	42°	66.0°	W.
Total	158	115	93	97	53.75	37	......	......	......	......
Mean	......	......	......	......	......	......	......	......	48.4°	......

SUMMARY, JANUARY 1, 1890, TO JUNE 30, 1908, INCLUSIVE.

	Maximum Temperature.	Minimum Temperature.	Mean Temperature.	Number of Clear Days.	Partly Cloudy Days.	Cloudy Days.	Days with .01 inch or more of Precipitation.	Total Precipitation, inches.
1890	91°	3°	48.3°	99	143	123	120	59.25
1891	94°	5°	49.4°	116	154	95	83	49.88
1892	92°	—1°	47.8°	147	116	103	89	42.56
1893	92°	—6°	46.5°	126	130	109	131	57.33
1894	93°	—9°	48.6°	110	130	125	114	48.19
1895	93°	—7°	48.2°	128	114	123	108	49.28
1896	93°	—11°	47.7°	131	112	123	109	49.87
1897	90°	—1°	48.3°	129	126	110	128	54.25
1898	95°	—4°	48.8°	110	114	141	131	72.21
1899, Jan. 1, to June 30	95°	—10°	42.1°	77	44	60	59	26.79
July 1, 1899, to June 30, 1900	90°	—5°	48.3°	141	113	111	102	51.67
July 1, 1900, to June 30, 1901	97°	—9°	48.4°	134	97	134	114	48.47
July 1, 1901, to June 30, 1902	93°	—1°	48°	138	116	111	109	53.14
July 1, 1902, to June 30, 1903	90°	—12°	48.3°	138	96	131	103	59.27
July 1, 1903, to June 30, 1904	93°	—16°	45.7°	156	107	103	118	50.06
July 1, 1904, to June 30, 1905	87°	—4°	45.3°	151	122	92	99	41.64
July 1, 1905, to June 30, 1906	92°	—3°	48.4°	175	99	91	97	53.57
July 1, 1906, to June 30, 1907	90°	—9°	46.5°	136	114	115	120	48.01
July 1, 1907, to June 30, 1908	89°	—4°	48.4°	158	115	93	97	53.75

Average temperature, 18½ years, 47.5°. Average precipitation, 18½ years, 51.01 inches.

REPORT OF THE TREASURER.

THE RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, *in account with the* UNITED STATES APPROPRIATIONS, 1907–1908.

DR.

	Hatch Fund.	Adams Fund.
To balance from appropriations for 1906–7	$——	$——
Receipts from the treasurer of the United States as per appropriations for fiscal year ended June 30, 1908, under acts of Congress approved March 2, 1887 (Hatch Fund), and March 16, 1906 (Adams Fund)	$15,000 00	$9,000 00

CR.

	Abstract.	Hatch Fund.	Adams Fund.
By Salaries	1	$8,193 23	$5,919 27
Labor	2	1,788 03	1,096 57
Publications	3	121 83	....
Postage and stationery	4	283 49	11 44
Freight and express	5	132 96	61 85
Heat, light, water, and power	6	612 36	477 72
Chemical supplies	7	130 83	120 71
Seeds, plants, and sundry supplies	8	370 37	207 72
Fertilizers	9	165 86	101 03
Feeding stuffs	10	839 82	481 16
Library	11	718 63	128 78
Tools, implements, and machinery	12	230 75	52 00
Furniture and fixtures	13	489 08	2 50
Scientific apparatus	14	158 76	106 45
Live stock	15	....	115 56
Traveling expenses	16	192 95	112 24
Contingent expenses	17	15 00	....
Buildings and land	18	556 05	5 00
Balance		....	....
Total		$15,000 00	$9,000 00

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Rhode Island Agricultural Experiment Station for the fiscal year ended June 30, 1908; that we have found the same well kept and classified as above; that the receipts for the year from the Treasurer of the United States are shown to have been $15,000, under the act of Congress of March 2, 1887, and $9,000, under the act of Congress of March 16, 1906, and the corresponding disbursements $15,000 and $9,000; for all of which proper vouchers are on file, and have been by us examined and found correct, thus leaving balances of $0,000.00 and $0,000.00.

And we further certify that the expenditures have been solely for the purposes set forth in the acts of Congress approved March 2, 1887, and March 16, 1906, and in accordance with the terms of said acts, respectively.

(Signed) CHARLES DEAN KIMBALL,
R. S. BURLINGAME,
Auditors.

C. H. COGGESHALL, TREASURER, *in account with the* RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, *for the year ended June* 30, 1908.

DR.

To balance on hand	$3,947 94	
Receipts from other sources than the United States for the year ended June 30, 1908	1,338 46	
Total		$5,286 40

CR.

By Labor	$ 75	
Postage and stationery	96	
Freight and express	33 84	
Chemical supplies	70	
Seeds, plants, and sundry supplies	13 37	
Fertilizers	55 80	
Tools, implements, and machinery	21 69	
Furniture and fixtures	79 65	
Traveling expenses	6 82	
Contingent expenses	54 35	
Buildings and land	2 45	
Balance	5,016 02	
Total		$5,286 40

This certifies that we, the undersigned, duly appointed auditing committee of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts, have examined the account of the Treasurer of the College, C. H. Coggeshall, and have found the same correct, with an expenditure of $270.38 on the Miscellaneous Account of the Experiment Station, thus leaving a balance of $5,016.02 in the treasury.

(Signed) CHARLES DEAN KIMBALL,
R. S. BURLINGAME,
Auditors.

EXCHANGES.

Agricultural Advertising, Chicago, Ill.
Agricultural Epitomist, Spencer, Ind.
Agricultural Gazette of New South Wales, The, Sydney, Austral
Agricultural Ledger, The, Calcutta, India.
Agricultural Student, The, Columbus, Mo.
A Lavoura, Boletim da Sociedade Nacional de Agricultura, Rio Janeiro, Brazil.
American Bee-Keeper, The, Fort Pierce, Fla.
American Cultivator, The, Boston, Mass.
American Farm World, The, Augusta, Maine.
American Fertilizer, The, Philadelphia, Pa.
American Fruit and Nut Journal, Peterburg, Va.
American Home Magazine, New York City.
American Hay, Flour, and Feed Journal, New York.
American Philosophical Society, Proceedings of the Society.
American Poultry Advocate, Syracuse, N. Y.
American Poultry Journal, Chicago, Ill.
American Sheep Breeder and Wool Grower, The, Chicago, Ill.
American Stock Farm, Springfield, Ohio.
American Stock Keeper, The, Boston, Mass.
American Sugar Industry and Beet Sugar Gazette, The, Chicago,
Annales de Gembloux, Gembloux, Belgium.
Arboriculture, Connersville, Ind.
Better Fruit, Hood River, Oregon.
Boletim da Agricultura, Saõ Paulo, Brazil.
Boletim do Museu Goeldi, Pará, Brazil.
Boletín del Ministerio de Agricultura, Buenos Ayres, South Ameri
Boletin Official de la Secretaria de Agricultura, Habana, Cuba.

Breeder's Gazette, Chicago, Ill.

Bulletins of the Botanical Department of Jamaica, and Reports of Public Gardens and Plantations.

Bulletins of the Hygienic Laboratory, Treasury Department, Washington, D. C.

Bulletins of the New York State Museum.

Cattle Specialist, The, Waukesha, Wis.

Chicago Daily Drover's Journal, Chicago, Ill.

Colman's Rural World, St. Louis, Mo.

Connecticut Farmer, The, New Haven, Conn.

Cotton Seed, The, Atlanta, Ga.

Elgin Dairy Report, The, Elgin, Ill.

Evening Tribune, The, Providence, R. I.

Farm and Stock, St. Joseph, Mo.

Farm Journal, The, Philadelphia, Pa.

Farm Poultry Monthly, The, Boston, Mass.

Farm Press, Chicago, Ill.

Farm Progress, St. Louis, Mo.

Farm, Stock, and Home, Minneapolis, Minn.

Farmer's Advocate, London, Ontario, and Winnipeg, Manitoba.

Farmer's Guide, The, Huntington, Ind.

Farmers' Review, The, Chicago, Ill.

Feather, The, Washington, D. C.

Feathered World, The, London, England.

Flour and Feed, Milwaukee, Wis.

Fruit Grower, The, St. Joseph, Mo.

Garden Magazine, The, New York City.

Geflügel-Züchter, Hamburg, Wis.

Green's Fruit Grower, Rochester, N. Y.

Guernsey Breeders' Sale List & Bulletin, Peterboro, N. H.

Gulf Coast Farmer, Brownsville, Tex.

Hoard's Dairyman, Fort Atkinson, Wis.

Holstein-Friesian Register, Brattleboro, Vt.

Homestead, Des Moines, Iowa.

Hospodářské Listy, Chicago, Ill.
Illuminated World Life, Minneapolis, Minn.
Indian School Journal, The, Chilocco, Okla.
Indiana Farmer, Indianapolis, Ind.
Industrious Hen, The, Knoxville, Tenn.
Inland Poultry Journal, Indianapolis, Ind.
Jewish Farmer, The, New York City.
Journal Board of Agriculture, London, England.
Journal of Department of Agriculture, Perth, Western Austra
Journal Royal Horticultural Society, London, England.
Kansas Farmer, Topeka, Kansas.
Kimball's Dairy Farmer, Waterloo, Iowa.
Long Island Agronomist, Huntington, L. I., N. Y.
Market Growers Journal, The, Louisville, Ky.
Maryland Agricultural Quarterly, College Park, Md.
Metropolitan and Rural Home, The, New York City.
Miscellaneous Publications, Departments of Agriculture and Mi
Natal, Africa.
Minnesota and Dakota Farmer, Brookings, S. D.
National Grange, Philadelphia, Pa.
National Stockman and Farmer, Pittsburg, Pa.
New England Farmer, The, Brattleboro, Vt.
New England Homestead, The, Springfield, Mass.
New Hampshire Farmer and Weekly Union, Manchester, N. H.
New York Farmer, The, Port Jervis, N. Y.
New Zealand Dairyman, The, Wellington, N. Z.
Northwest Horticulturist, Tacoma and Seattle, Wash.
Nut Grower, The, Poulan, Ga.
O Criador Paulista, Saõ Paulo, Brazil.
Ohio Farmer, The, Cleveland, Ohio.
Oregon Agriculturist, Portland, Oregon.
Pacific Dairy Review, The, San Francisco, Cal.
Pigeons, Peotone, Ill.
Poultry, Peotone, Ill.

Poultry Gazette, The, Clay Center, Neb.
Poultry Herald, St. Paul, Minn.
Poultry Husbandry, Waterville, N. Y.
Poultry Keeper, The, Quincy, Ill.
Poultry Success, Springfield, Ohio.
Poultry Topics, Lincoln, Neb.
Practical Dairyman, New York City.
Practical Farmer, The, Philadelphia, Pa.
Prairie Farmer, The, Chicago, Ill.
Publications of Agricultural Research Institute, Pusa, India.
Publications of Armstrong College, New Castle-upon-Tyne, England.
Publications of Department of Agriculture of Victoria, Melbourne, Australia.
Publications of Department of Agriculture, Ontario and Ottawa, Canada.
Publications of Department of Agriculture, Tallahassee, Florida.
Publications of Department of Agriculture, Altanta, Ga.
Publications of Department of Agriculture, Mysore State, India.
Publications of Department of Agriculture, Wellington, New Zealand.
Publications of Department of Agriculture, Harrisburg, Pa.
Publications of Entologizka Foreningen, Stockholm, Sweden.
Publications of Estación Agricola Experimental de Ciudad Juárez, Chihuahua, México.
Publications of Hawaiian Sugar Planters' Association, Honolulu, H. T.
Publications of Imperial Agricultural Experiment Station, Nishgahara, Tokyo, Japan.
Publications of Public Museum of Milwaukee, Milwaukee, Wis.
Publications of Smithsonian Institution, Washington, D. C.
Publications of State Board of Agriculture, Augusta, Maine.
Publications of State Board of Agriculture, Boston, Mass.
Publications of State Board of Agriculture, Raleigh, N. C.

Publications of State Board of Agriculture, Columbus, Ohio.
Publications of State Board of Agriculture, Providence, R. I.
Publications of State Board of Entomology, Atlanta, Ga.
Publications of State Board of Health, Concord, N. H.
Publications of University College, Bangor, North Wales.
Rakings, York, England.
Reliable Poultry Journal, Quincy, Ill.
Republic, The, St. Louis, Mo.
Rock Products, Chicago, Ill.
Rural New Yorker, The, New York City.
Rural World, The, London, England.
Skandinavisk Farmer Journal, Minneapolis, Minn.
Southern Farm Magazine, Baltimore, Md.
Southern Fruit Grower, The, Chattanooga, Tenn.
Southern Planter, The, Richmond, Va.
Spokesman Review, The, Spokane, Wash.
Standard, The, Quincy, Ill.
Suburban Life, Harrisburg, Pa.
Successful Farming, Des Moines, Ia.
Successful Poultry Journal, Chicago, Ill.
Texas Farmer, Dallas, Texas.
Town and Country Journal, San Francisco, Cal.
Up-to-Date Farming, Indianapolis, Ind.
Wallace's Farmer, Des Moines, Iowa.
Weddel, W., & Co.'s Colonial Dairy Produce Report, London, England.
Western New York Apple, The, Barker, N. Y.
Wilson Bulletins, Wilson Ornithological Club, Oberlin, Ohio.
Wisconsin Agriculturist, The, Racine, Wis.
Year Book, and current publications of the Deutschen Landwirtschafts-Gesellschaft.

Directions for Binding the Bulletins and Reports of the Rhode Island Experiment Station.

Vol.	1-3,*	Bulletins	1-9,	Reports,	1-3,	1888-1890.
"	4,	"	10-14,	Report,	4,	1891.
"	5,	"	15-20,	"	5,	1892.
"	6,	"	21-26,	"	6,	1893.
"	7,	"	27-30,	"	7,	1894.
"	8,	"	31-35,	"	8,	1895.
"	9,	"	36-42,	"	9,	1896.
"	10,	"	43-46,	"	10,	1897.
"	11,	"	47-51,	"	11,	1898.
"	12,	"	52-55,	"	12,	1899.
"	13,	"	56-69,	"	13,	1899-1900.
"	14,	"	70-78,	"	14,	1900-1901.
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"	18,	"	102-107,	"	18,	1904-1905.
"	19,	"	108-114,	"	19,	1905-1906.
"	20,	"	115-122,	"	20,	1906-1907.
"	21,	"	123-129,	"	21,	1907-1908.

* Vols. 1-3 in one cover. Beginning with volume 4, a title page and index for each volume is to be found at the end of the annual report for each year. The year covered by a volume formerly was the calendar year, but now it extends from July 1 to June 30. Each volume, beginning with volume 4, is paged separately. The Bulletins of a given year precede the Report, and the latter is paged in continuation of the last Bulletin belonging in the volume.

BULLETINS

AND

ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDED JUNE 30,

1908.

PROVIDENCE:
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1908.

INDEX OF THE BULLETINS

AND

TWENTY-FIRST ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDED JUNE 30, 1908.

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